FCF Combustion Integrated Rack Delta-PDR

Marty O'Toole

February 13, 2001

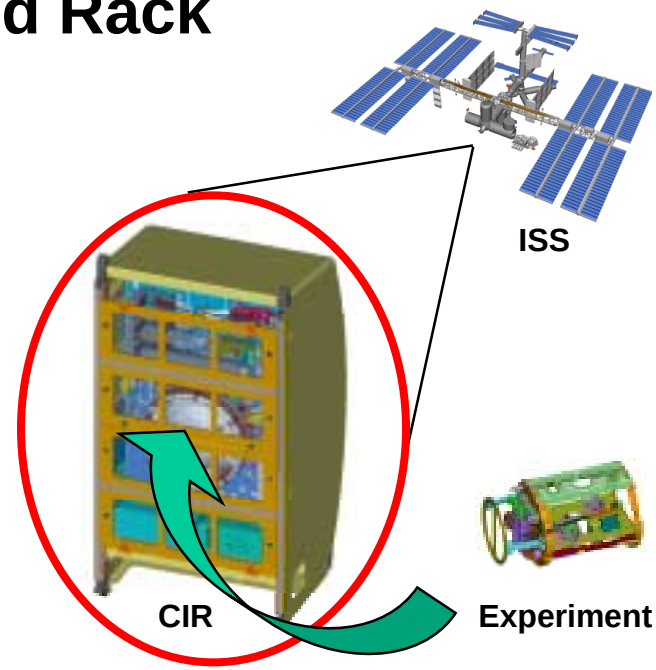
Combustion Integrated Rack

Mission and Operations Concept

- Develop a modular, multi-user facility that will support a diverse range of microgravity combustion science investigations on board the International Space Station.
- Operate initially in ISS as an independent rack. After other FCF racks are deployed to ISS, operate in conjunction with those racks to leverage their capabilities and services to meet Level 1 science requirements.

Concept and Key Design Drivers

- Minimize PI Costs: Provide the majority of the required hardware and infrastructure to perform combustion science investigations in ISS (the remaining equipment is experiment specific).
- Range of Diagnostics: Provide a modular, flexible design to support many combustion experiments with diverse science requirements, as defined in the SRED and individual experiment SRDs.
- Maintainability: Design for permanent installation in ISS. Key components are on-orbit replaceable to enable upgrades, incorporate new technology and/or provide for on-orbit maintenance during the >10 year life span of the facility.
- ISS resource constraints: Minimize crew time, data d/l, power, energy and up-mass resource usage thereby maximizing research opportunities and science return from ISS.



Microgravity Combustion Research Areas

- Laminar Flames
- Turbulent Combustion
- Smoldering Combustion
- Reaction Kinetics
- Condensed Phase Organic Fuel Combustion
- Flame Spread and Fire Suppressants
- Droplet and Spray Combustion
- Soot and Polycyclic Aromatic Hydrocarbons
- Materials Synthesis

CIR Key Design Drivers

FCF-DOC-002
Science Requirement
Envelope Document

SSP 57000
Pressurized Payloads
IRD Rev. E

NSTS 1700.7B
Safety Policy
and Requirements

FCF-SPEC-0001
System Specification
Rev. Draft 5.1

FCF-SPC-0001
System Specification
Rev. 6.0

FCF-SPC-0002
CIR Prime Item
Development Spec

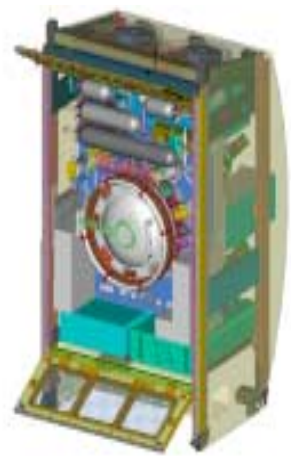
Project Plan

MRDOC
SOW

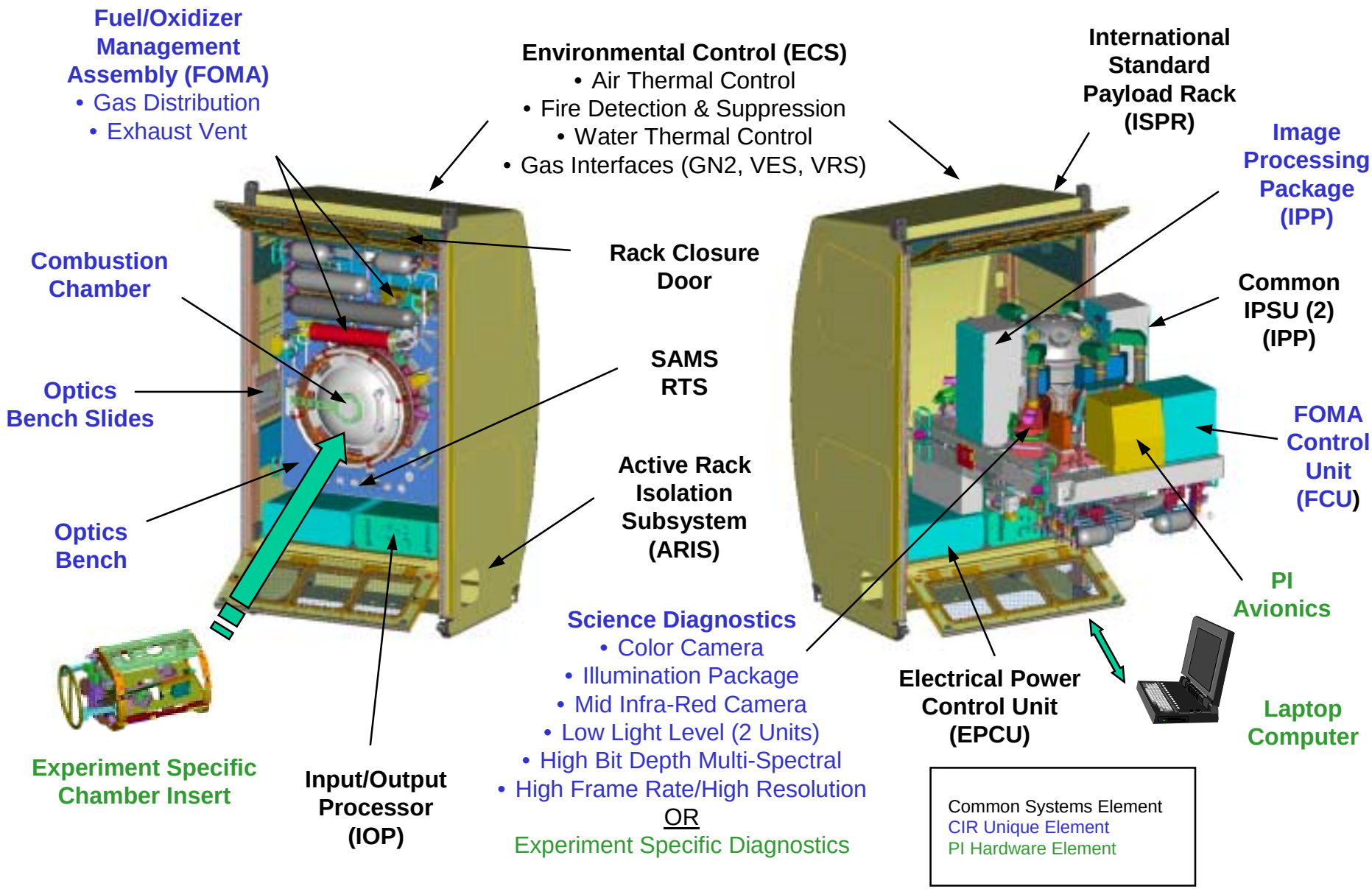
Project Plan

Goal to meet SRDs
Utilization of COTS

Maintainability
PI Experiment Cost
ISS Resource Allocation
Range of Diagnostics



CIR Elements / Subsystems



CIR Launch & Operating Configurations

Launch Configuration

Optics Bench Front View
(Doors closed & secured for launch)

Optics Bench
Rear View

Elements of CIR are Stowed for Launch in Foam Lined Resupply Lockers in Order to:

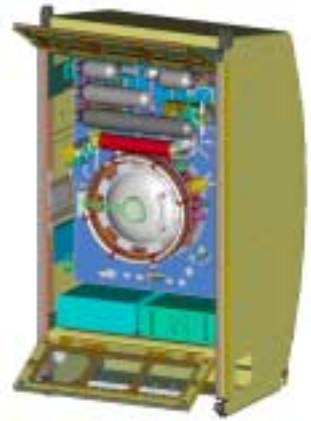
- Decrease mass to meet the integrated rack mass limitation of 804 kg for launch in the MPLM.
- Increase the natural frequency of the rack for launch
- Minimize environmental testing of packages which reduces development costs and enables use of COTS components.

CIR Stowed Items for Launch Include:

- Diagnostics Packages
- Image Processing Packages
- Experiment specific chamber insert & PI avionics
- FOMA gas bottles and filter cartridges
- Rack/Station interface umbilical set
- Some ARIS components

Operating Configuration

CIR Diagnostics and
Image Processing Packages
Installed by Crew On-Orbit

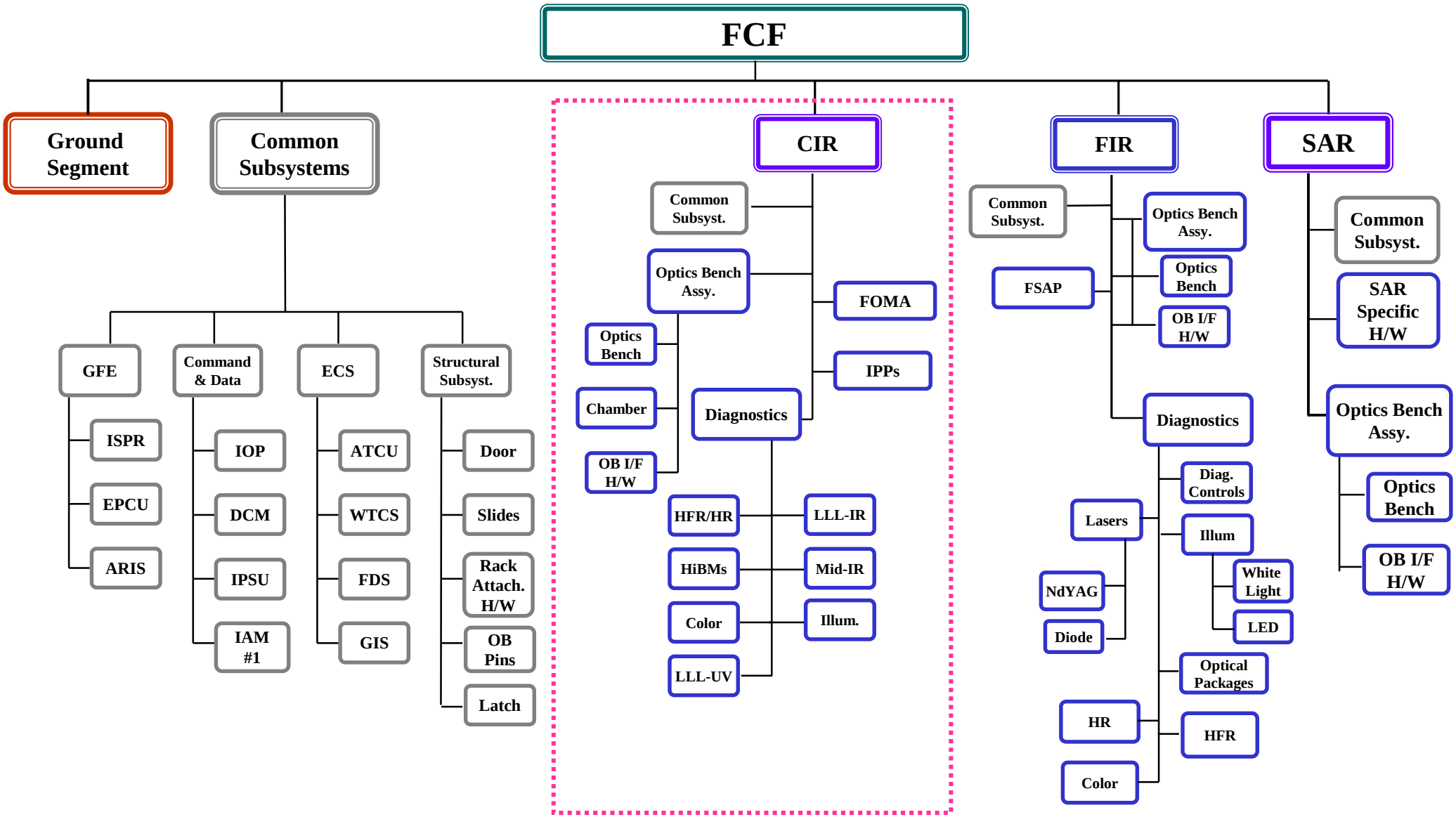


CIR Gas Bottles, Filters and
Experiment Specific Hardware
Installed by Crew On-orbit

CIR On-Orbit Configurable Elements:

- Science Diagnostics
  - HFR/HR, HiBM, LLL-UV, LLL-IR, Color, Mid-IR Cameras
  - Illumination Package
- Avionics Packages
  - Image Processing Packages
  - Common IPSU
  - FOMA Control Unit
  - Input/Output Processor
- FOMA Components
  - Gas Bottles
  - Adsorber Cartridges
- Experiment Provided Hardware
  - Chamber Insert
  - PI Specific Diagnostics Packages
  - PI Specific Avionics

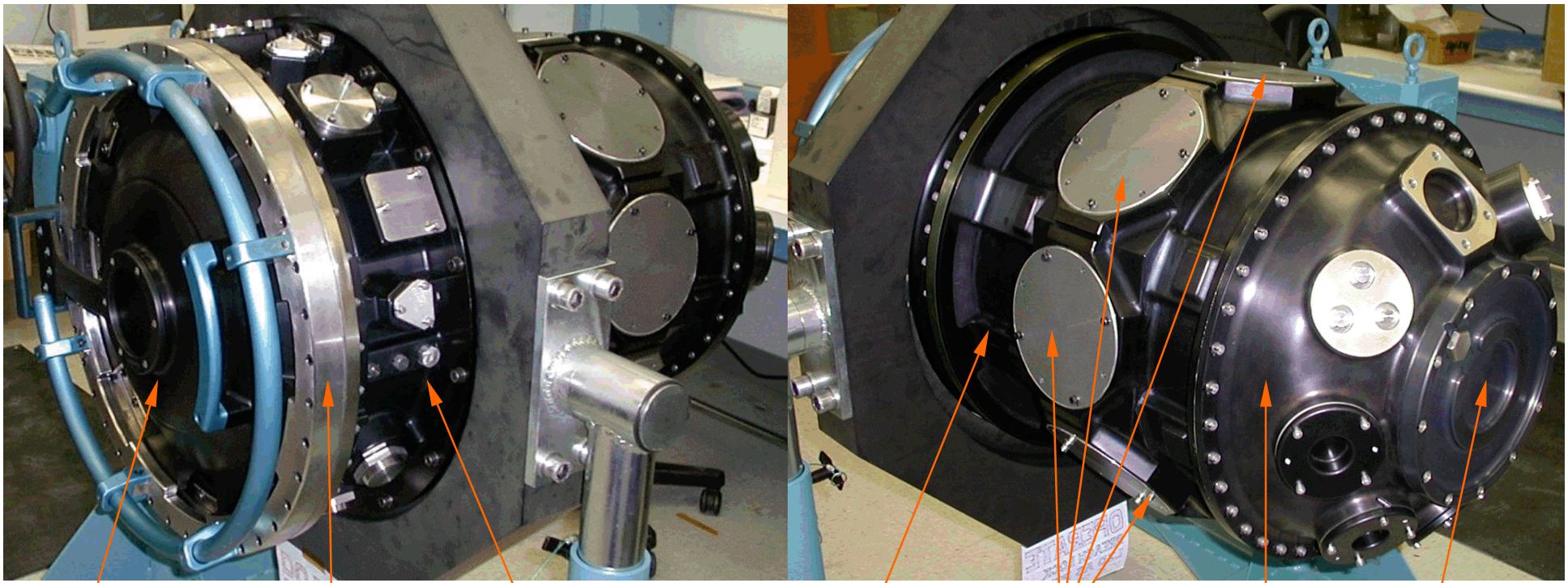
FCF Hardware Tree



CIR Structural/ Mechanical Systems

Combustion Chamber

Identification of Major Components



Combustion Chamber – Continued

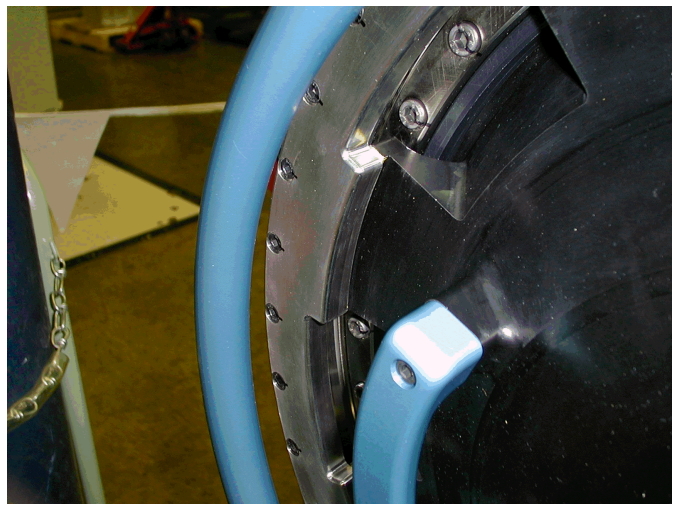
Functions

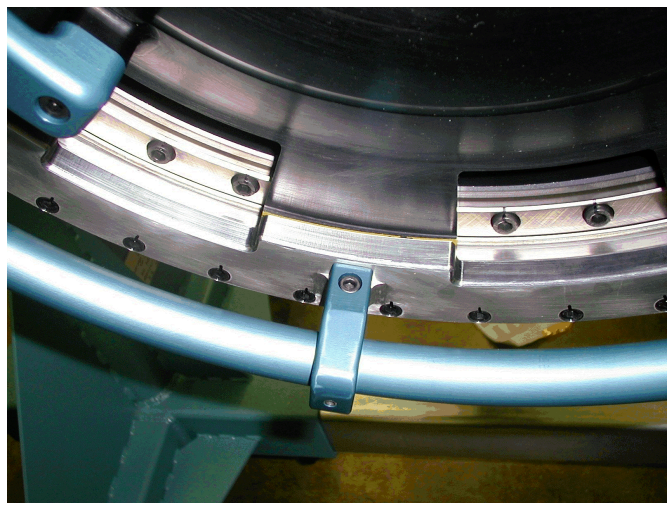
- Provides structural support for the PI Hardware with on orbit access for installation and removal
- PI's can operate at pressures ranging from 0.02 to 3 atmospheres and is designed to contain pressures up to 9 atmospheres
- The chamber contains 8 replaceable windows spaced 45° apart
- Windows replaced from the inside
  - No tools required for replacement
  - Ratcheting mechanism for vibration resistance
- The baselined window material is Sapphire (Al202) which has a transmission wavelength of 0.25-5.5 µm

Combustion Chamber – Continued

Functions

- The Chamber door is an 8 tab breech device that allows for easy opening.
- Breech lock hinged front lid. No tools are required to open the front end cap. A large handle is provided for easy opening and closing.
- Designed to accommodate a Chamber Insert Assembly up to 396 mm in diameter. The chambers minimum diameter is 400 mm.
- Interfaces internal to chamber provided through the IRR including electrical, fluid and gas.
- The chamber has four thermistors, 2 located on the rear end cap and 2 located on the IRR.

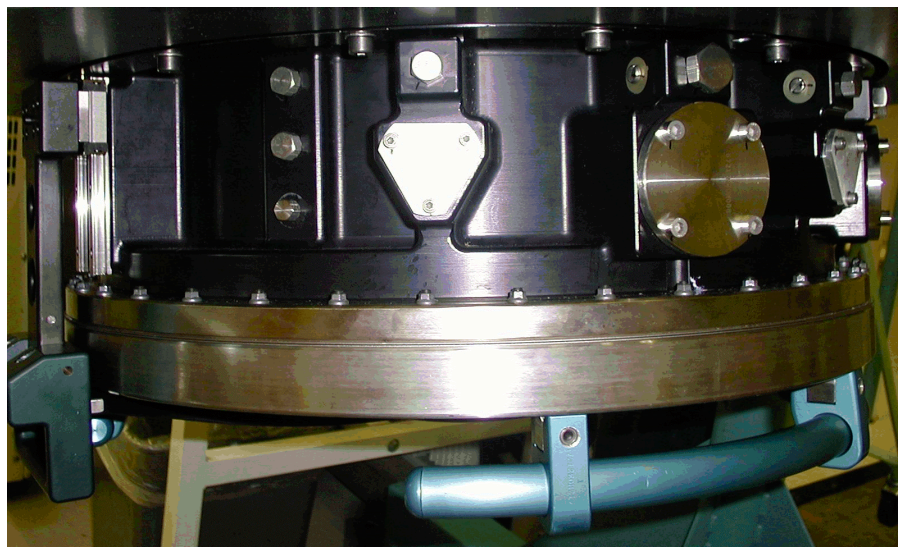




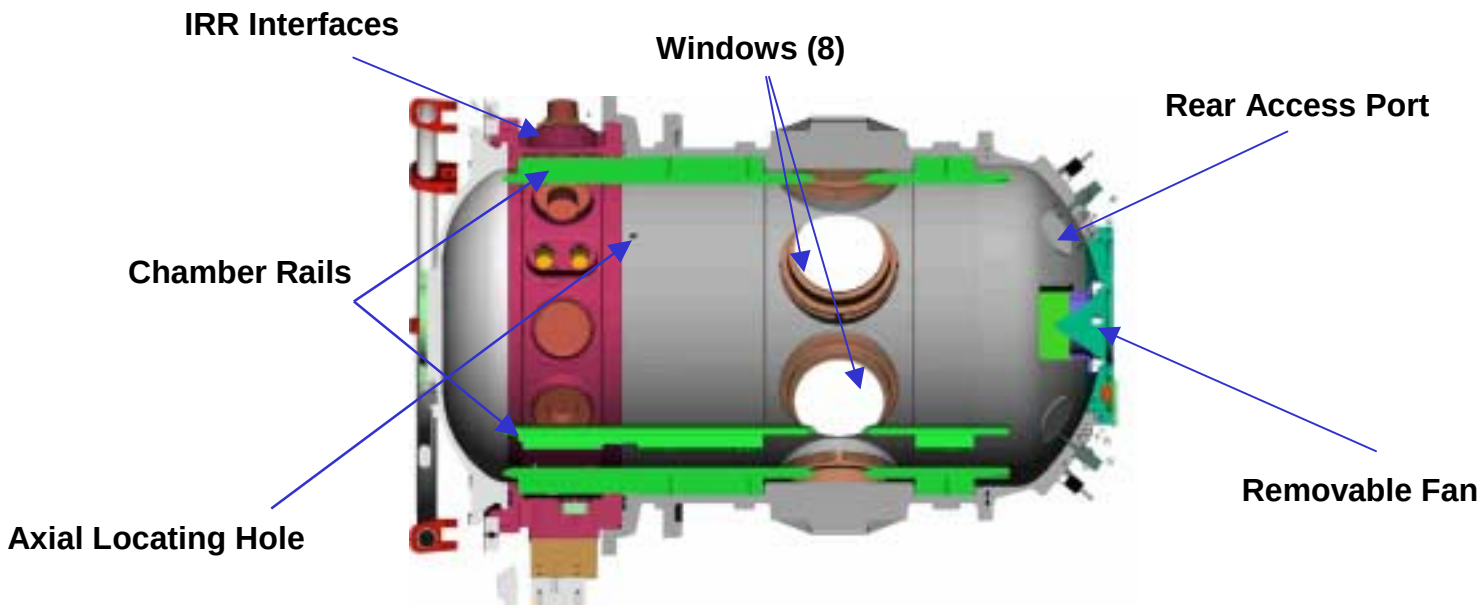
Combustion Chamber – Continued

Functions

- The chamber has four pressure transducers, 2 located on the rear end cap and 2 located on the IRR. Three can measure to 50 ± .05% psia and one can measure 150 ± .05% psia.
- Three pressure switches are located on the chamber, 2 on the rear end cap and 1 in the IRR. One switch is set for 127 ± 5 psia, the other two are set for 1 + 3.5 psia.
- The chamber has two pumps located on the rear end cap that can be utilized to circulate the atmosphere through an adsorber cartridge.
- A mixing fan is located at the rear of the chamber to ensure the proper consistency of gas blends inside the chamber.

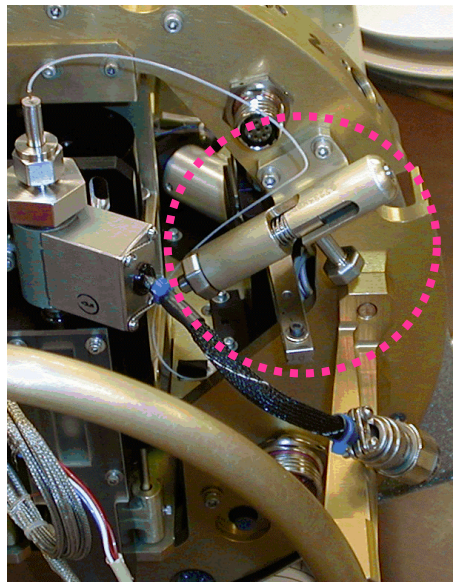


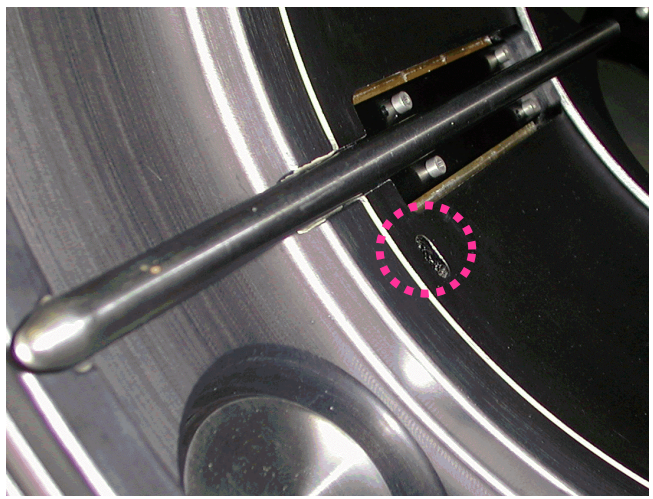
Interfaces – Chamber



Combustion Chamber

Interfaces – Chamber – Continued

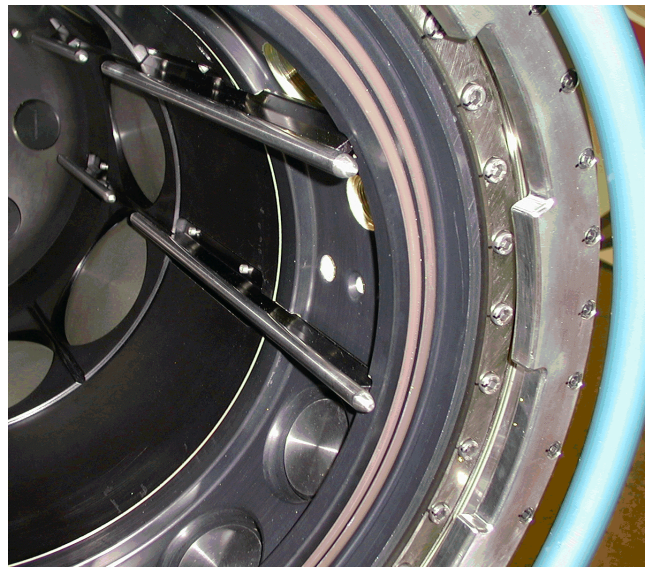


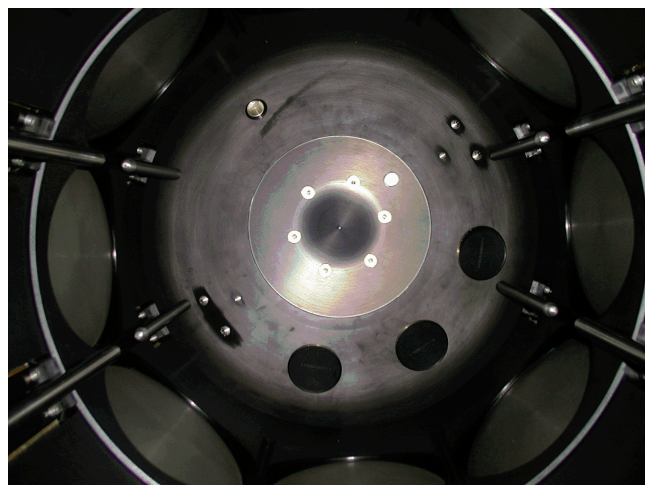


- Shown in the top picture to the left is an example of a locating pin used to position a CIA axially inside the chamber. This pin interfaces with slotted holes located on the window section of the chamber.
- The picture below and to the left highlights one of the radially slotted pockets into which the locating pin is inserted. Four slotted holes are located 262.025 mm from the window center allowing the CIA to be inserted in any of four orientations utilizing a single pin.
- Hard stops are located 217 mm back from the center of the windows. The hard stops should not be used to locate the CIA and are there to prevent the CIA from impacting the hardware in the rear end cap.

Interfaces – Chamber – Continued

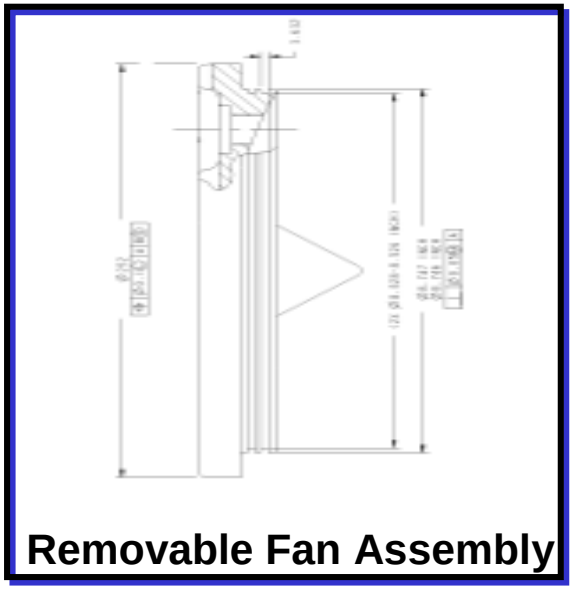
- Both figures show the guide rails used to align and insert the Chamber Insert Assembly (CIA) into the combustion chamber.
- The rails are pinned to the walls of the chamber to allow for accurate positioning of the combustion event.
- The rails are made of stainless steel and are ½” in diameter.
- They extend across the IRR to both protect the instrumentation around the IRR and to make insertion of the CIA easier.
- The rails extend from the front of the chamber to the windows and break where they would interfere with the 115 mm diameter clear field of view of the windows.
- Rail continue back from the windows and provide hard stops to prevent contact with rear of chamber.



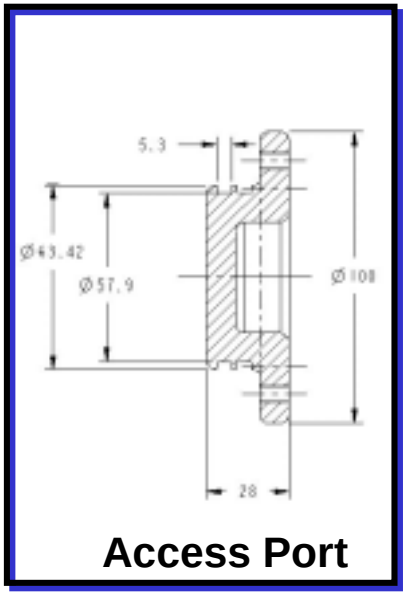


Interfaces – Access Ports and Removable Fan

- A single access port and removable fan assembly on the chamber rear end cap can be replaced by PI specific equipment with accompanying analysis and testing showing that equipment will withstand pressure loads.
- Both ports utilize dual, static O-rings to seal.
- Jack-screws are utilized to remove the assemblies occupying the ports.
- The color figure to the right shows the extra port located on the IRR that can allow PI specific hardware to be inserted into the chamber.
- The port utilizes a 0.75-16 inch Spiralock thread port per MS33649-08.



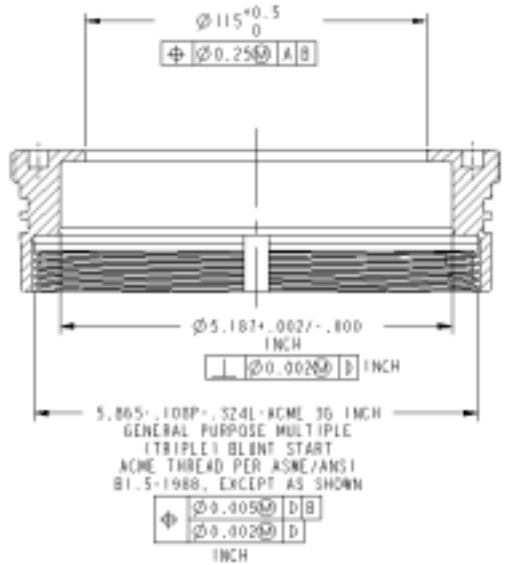
Removable Fan Assembly

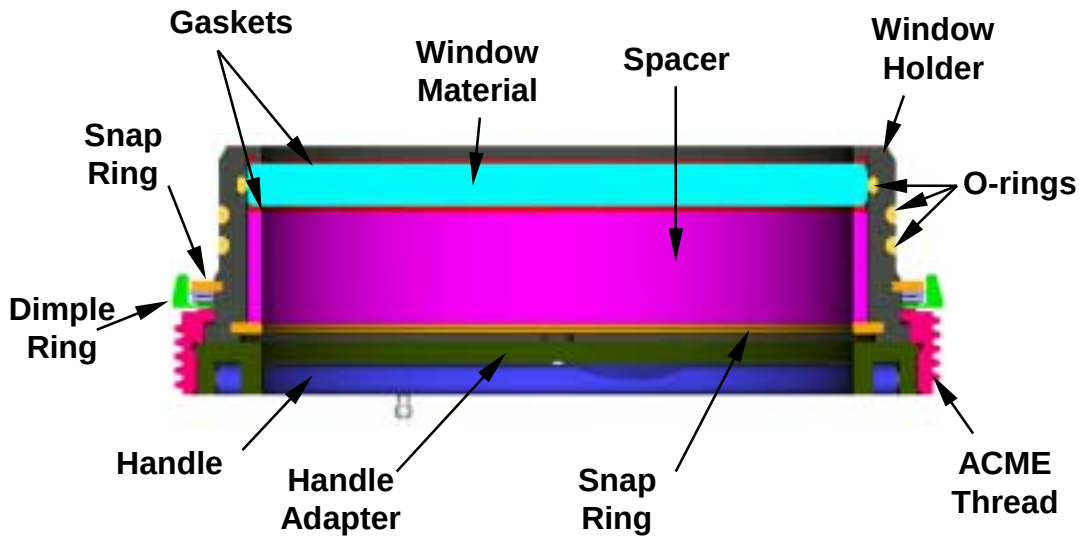


Access Port

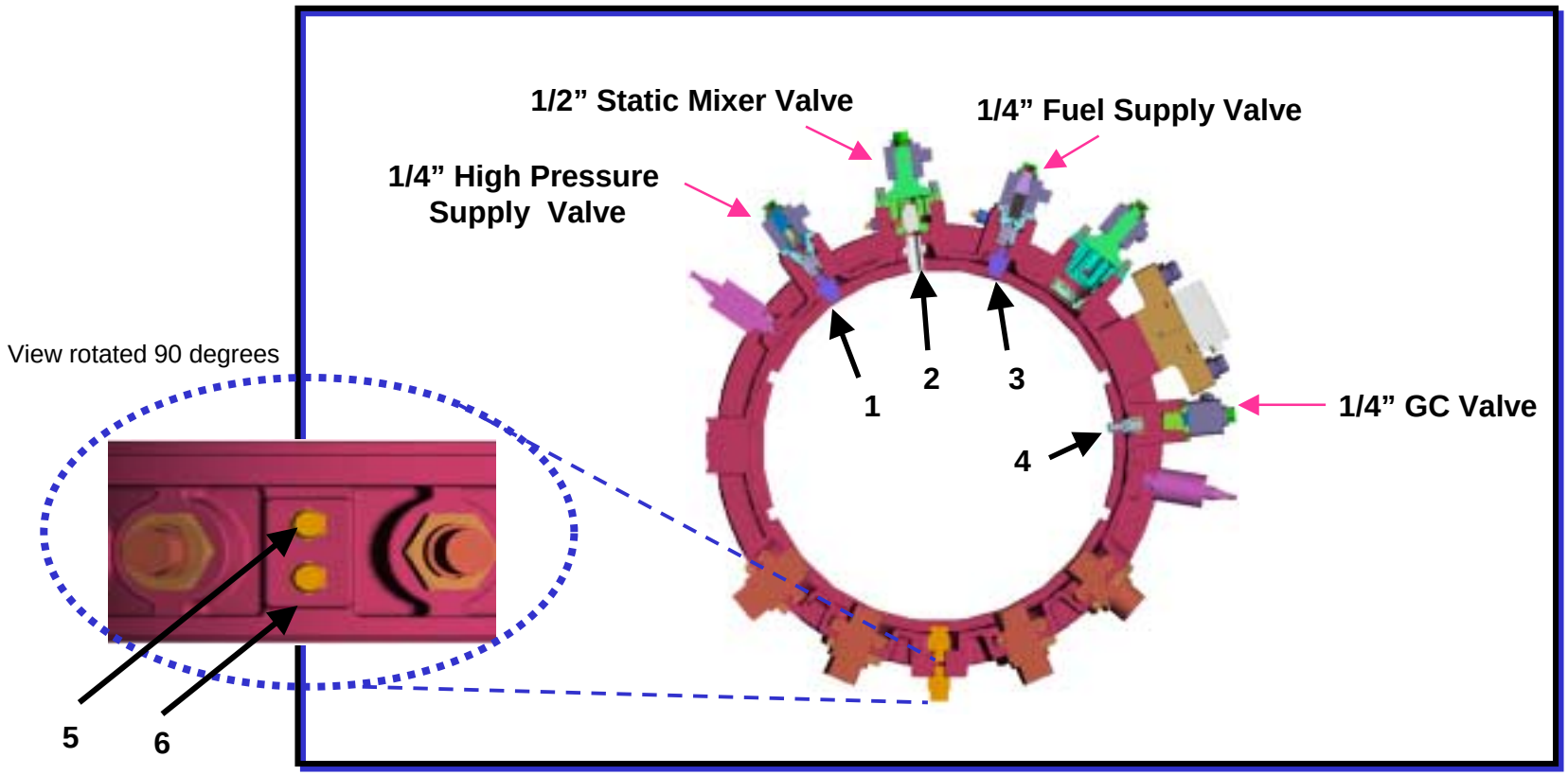
Interfaces – Window Inserts

- The 8 CIR window ports may be replaced with PI provided windows.
- The replaceable windows can utilize window materials from 8-29 mm thick by varying the spacer thickness.
- The windows have a clear aperture of 115 mm in diameter.
- Diagram to the right shows the FCF provided replaceable window insert into which the windows are installed.
- The replaceable window is shown in the color figure to the right.
- Window is composed of window holder, gasket, window material, o-ring, spacer, gasket, snap ring, handle, ACME thread, dimple ring, spring, spring retainer, and snap ring.





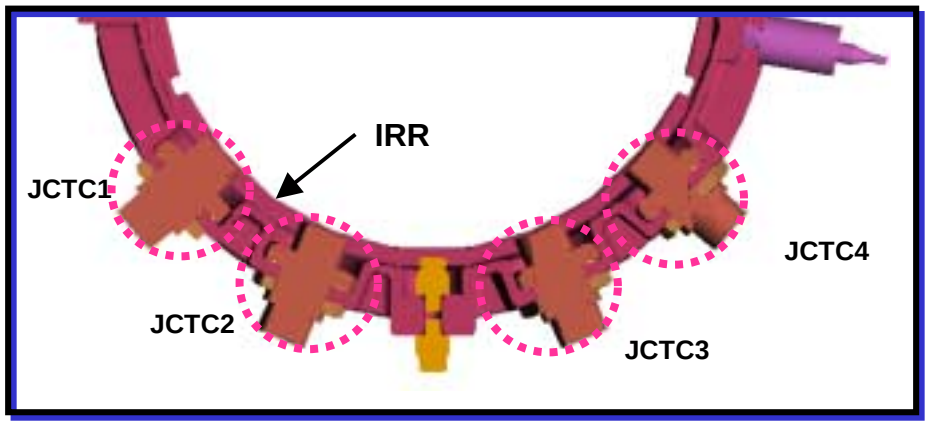
Fluid Interfaces – Interface Resource Ring



PI Interfaces to the CIR Fluids Systems via QD’s specified in the IDD

1	¼” High Pressure Supply Valve QD	5	¼” Cooling Water Inlet QD
2	½” Static Mixer Valve QD	6	¼” Cooling Water Outlet QD
3	¼” Fuel Supply Valve QD		
4	¼” GC Valve QD		

Electrical Interfaces – Interface Resource Ring



Four Electrical Feed-throughs

Insert Type MIL-C-38999 connectors

Current connector configurations are:

- JCTC1: Provides 40 pairs of #22 gauge wire between IRR and PI Avionics connector through the optics bench
- JCTC2: Provides 27 pairs of #20 gauge wire pairs between IRR and PI Avionics connector through the optics bench
- JCTC3: Provides 2 Fiber Optic, Single-Mode 9.0 Core/125 Cladding, 2 RG-179 coaxial cables and 5 pairs of #16 gauge wires to the PI avionics location through the optics bench
- JCTC4: Provides 49 pairs of #22 gauge wire pairs between IRR and PI Avionics connector through the optics bench

Combustion Chamber Testing

Hydrostatic test

- The chamber MDP is 135 psig (120 psig maximum internal pressure plus a complete loss of pressure in the cabin).
- The combustion chamber has been successfully hydrostatically tested to 1.5 times MDP (202.5 psig). No leaks occurred at this pressure.
- Results and procedure are documented the Hydrostatic Proof Pressure Test Plan – Combustion Chamber (EM), CIR-TEST-EM0016.

Vacuum helium leak check

- An helium leak check was performed on the chamber while it was at vacuum.
- No leak above 4.7 x 10-5 scc/sec of helium was observed during the leak check.

Pressurized leak check

- A pressurized helium leak check was performed on the chamber using 30 psig of helium.
- No leak above 1.62 x 10-6 scc/sec of helium was observed during the leak check.

Pressure Decay check

- The chamber was pressurized to 46 psig post hydrostatic test using nitrogen and held for 168 hours.
- No significant leak (when adjusted for temperature differences) was observed.

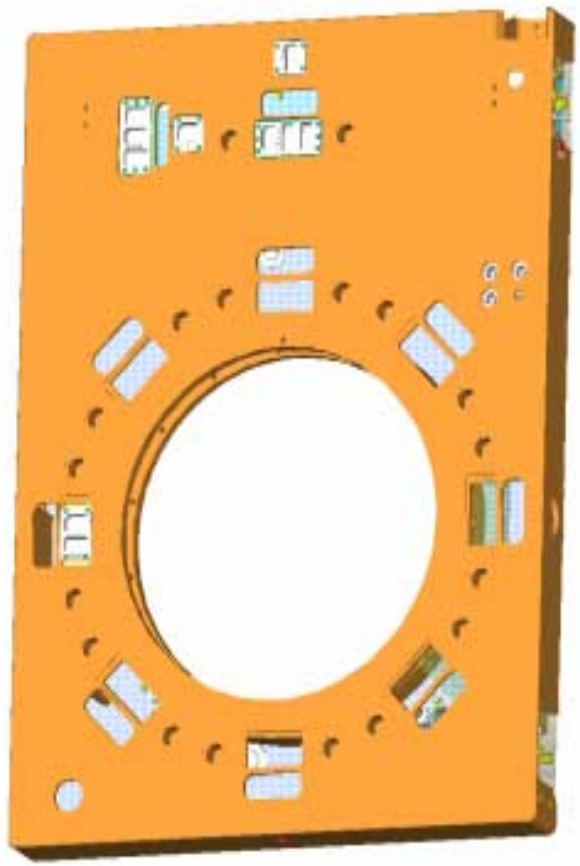
Sapphire Materials Testing

- The materials testing is described in Characterization of Fatigue Parameters and Fracture Toughness of Sapphire and Zinc Selenide, CIR-PLAN-0027.
- The GRC materials lab has completed sapphire R-plane testing which is the most critical fracture plane.
  - Preliminary test results are available, a formal report is expected in April 2001.
- Material properties data will used to develop a FLAGRO analysis.
  - A FLAGRO analysis is a fracture propagation program required by JSC to qualify the windows for flight.
- A FLAGRO analysis using preliminary test results indicates that an 8 mm thick window can be qualified for 4 x life using assumed pressure cycle load spectrum.

Optics Bench

Functions

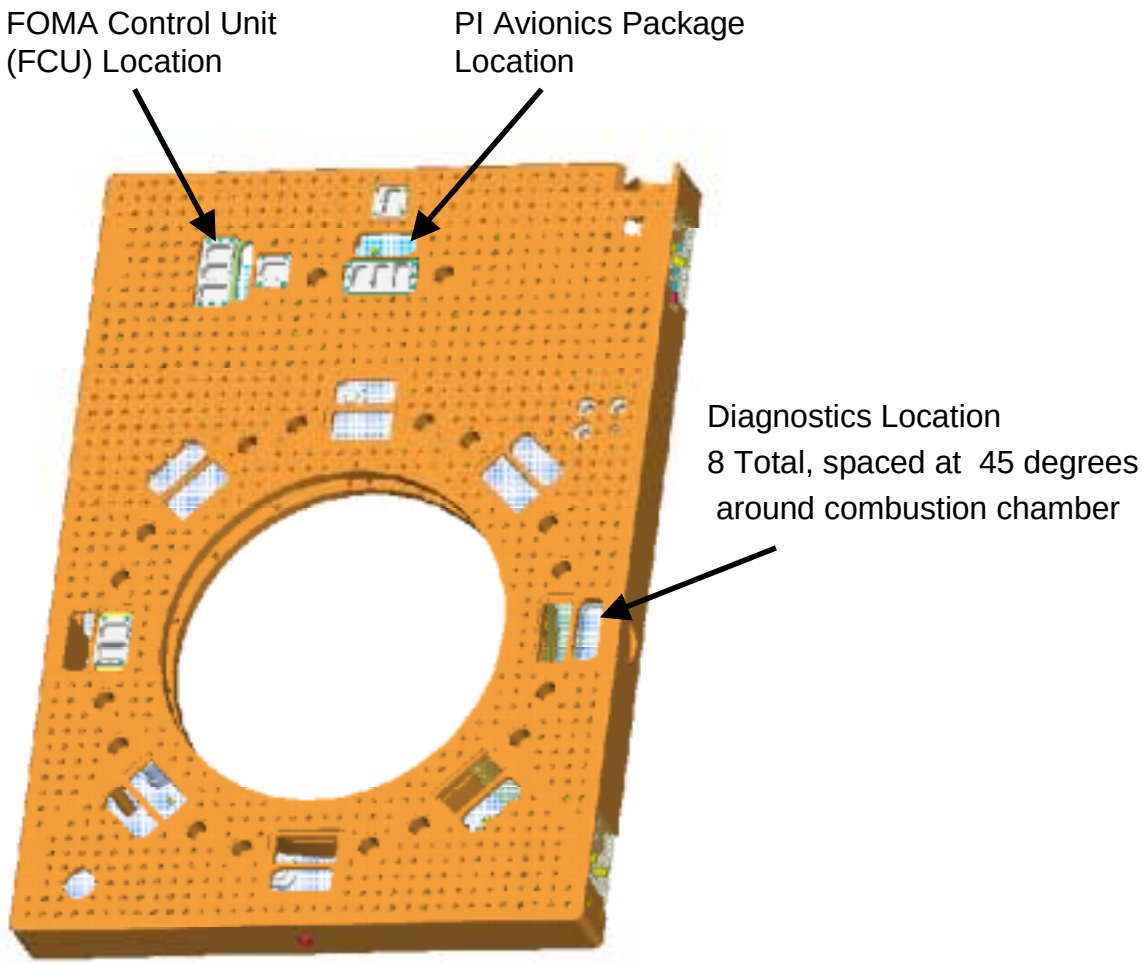
- Structural interface of avionics, diagnostic packages, chamber and FOMA components
- Along with its attachment hardware the optics plate is translated and rotated from its operating configuration
- Serves as a key element for re-configuration and maintenance of the CIR
- Serves as a cooling air plenum for distribution of ATCU outlet air
- Provide air cooling and interface to bench mounted components and IOP through UML cooling ports
- Provide electrical and data connections through UML connectors
- Structural interface to the rack



Rear Bench Assembly Interfaces

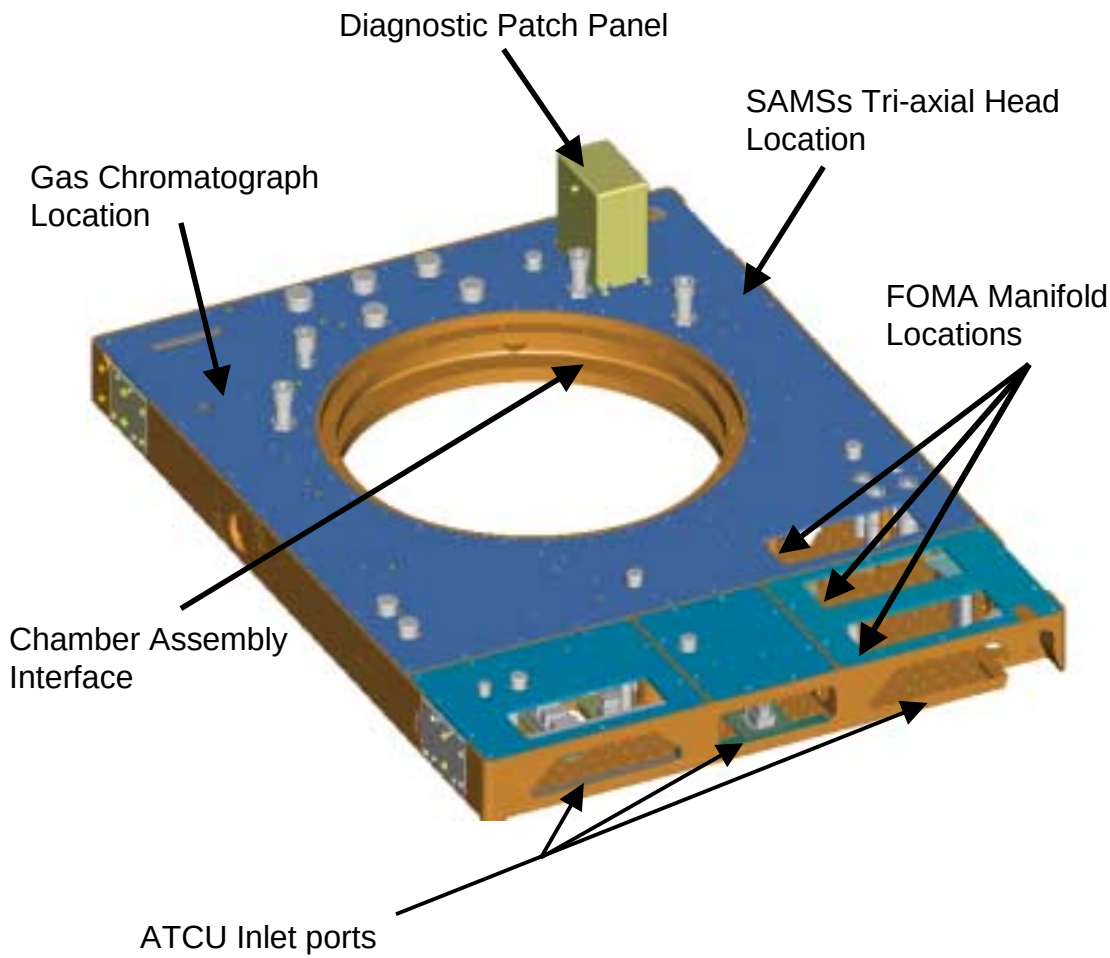
Rear Avionics Components

- CIR Diagnostics
  - Color Camera
  - High Frame Rate Camera
  - Near I/R system
  - HiBMs
  - UV
  - Illumination system
- FOMA Control unit
- PI Avionics



Front Optics Bench Interfaces

- Front Avionics mounted components
- Sams Head
- FOMA Manifolds
- Diagnostic Patch Panel
- Chamber Assembly
- Gas Chromatograph



Optics Bench – Rack Interfaces

4 Point Launch Constraint

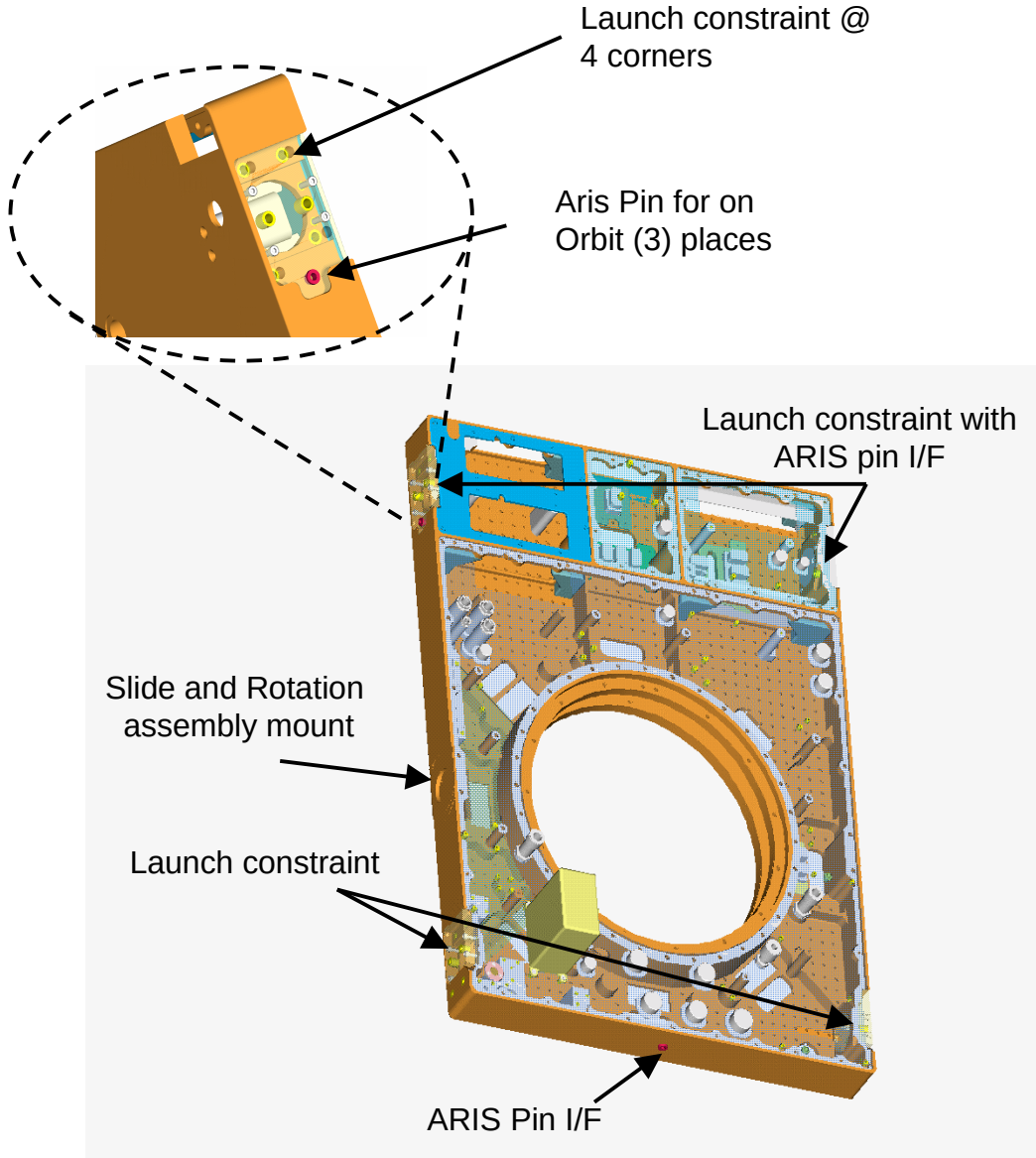
- For launch the Optics Bench is attached to the rack at each of four corner points with (6) M12 socket head cap screws.

3 point ARIS mount

- For on-orbit operations retractable restraint pins hold the optics bench into position at 3 locations.

Slide Assembly

- Slide assembly provides structural support for bench translation.



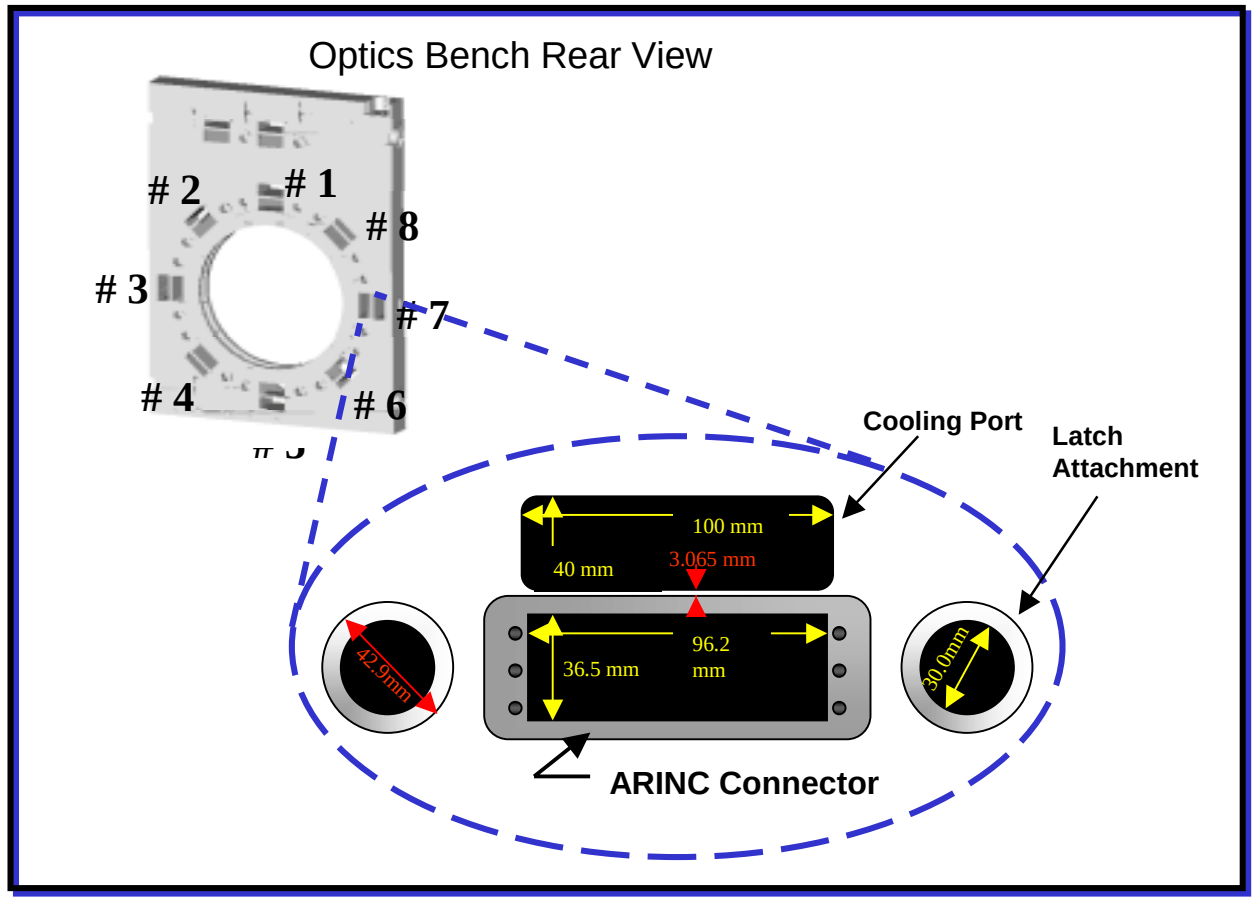
Optics Bench Cut-Away View

PI Interfaces – Optics Bench UMLs

UML 1- 8 Connector Specification

ARINC 404

- Receptacle: DSXN2R-S106P-S26S-6301
- Plug: DSXN2P-S106S-S26P-6001



PI Interfaces – Optics Bench

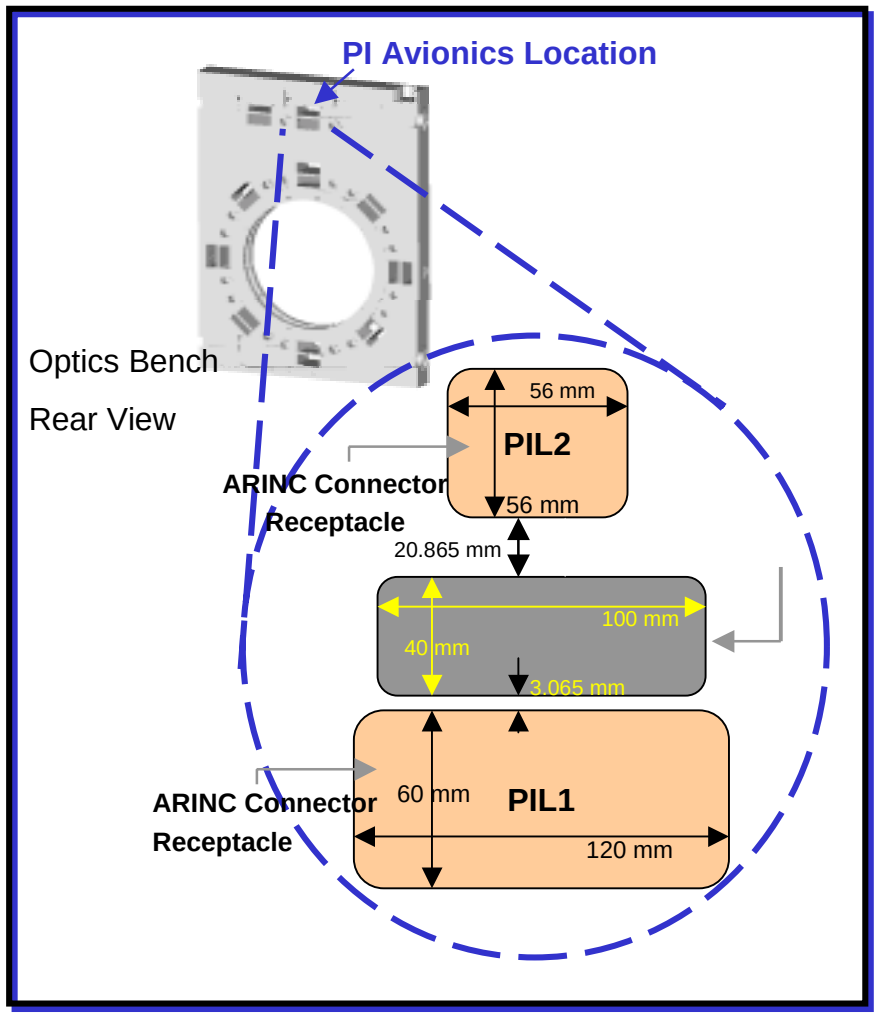
UML 9 Connector Specification

ARINC 404 (PIL1)

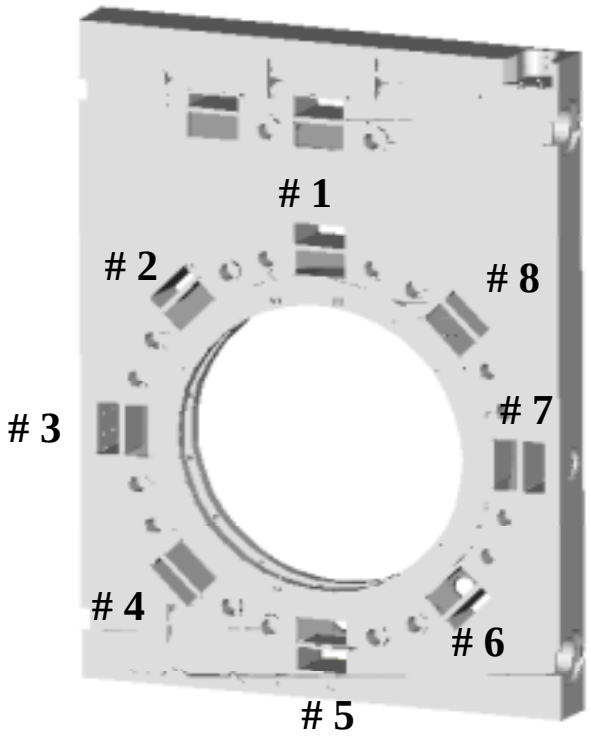
- Receptacle: DSXN3R-S106P-S106P-S57S-6301
- Plug: DSXN3P-S106S-S106S-S57P-6001

ARINC 404 (PIL2)

- Receptacle: DSXN1R-S26S-6301
- Plug: DSXN1P-S26P-6001



Optics Bench UML Services



Service	UML-1, 2,4,6,8	UML-3, 5,7	UML-9
8A, 28v Power Circuits	1	2	2
Ethernet Interface (100 BaseT)	1	2	1
Fiber Optic Lines	4	8	5
Camera Sync Interface	1	1	1
CAN Bus Interface	2	4	2
UML Location Identifier (6 bits)	1	2	0
Coaxial Lines	0	0	2
Differential Video (Line Pairs)	1	2	3
#22AWG Wires	24	24	178
#20 AWG Wires	0	0	27
#16 AWG Wires	0	0	10

Integrated Rack Structural Analysis

- **CIR PDR analysis (Boeing Rept. D683-56171-1, 12/14/98)**
  - Very preliminary FE model of CIR
  - No rack level strength issues
  - Natural frequency below 25 Hz
- **FIR PDR analysis (Boeing Rept. D683-56177-1, 10/31/00)**
  - Better FE representation of FCF Common Hardware
  - No rack level strength issues
- **CIR in on-orbit, science configuration sent to Boeing/Huntsville for ARIS controls analysis**
  - Lumped mass representation of ATCU, IOP & EPCU
  - Model transmitted 11/20/00

Integrated Rack Structural Analysis – Continued

- **In-Work**
  - CIR in on-orbit, science configuration for CIR generated micro-gravity disturbance analysis
    - Integrated model development in progress
    - Will incorporate detailed finite element models of ATCU and IOP
    - Currently using ATCU model to optimize ATCU isolation approach
- **Planned Efforts**
  - CIR CDR analysis
    - Launch/landing configuration
    - ISPR stress analysis conducted by Boeing
    - Will request coupled loads analysis
    - FE model will be transmitted to Boeing 2 mos. before CDR
  - UF-3 Verification Loads Analysis
    - As-built CIR in launch/landing configuration

CIR Structural Analysis Status Summary

Subsystem	Design Status	Analysis Status
Optics Bench Assembly	--	--
Chamber*	Complete	Complete
Optics Plate	Complete	Complete
Upper & Lower Support Brackets	In Process	Complete
FOMA Components	Complete	80 % Complete
Diagnostic Components	In Process	Pending
Deployment Slides	Complete	Complete
IOP	Complete	Complete
EPCU Rails/Brackets	Complete	Complete
ISPR Lower Center Post Structure	Complete	In Process
Environmental Control System	--	--
ATCU	Complete	Pending
WTCU	In Process	Pending
GIS	In Process	Pending
FDSS Probe Support Bracket	In Process	Pending
Rack Door	Complete	In Process

* Proof pressure tested at 1.5 times MDP

CIR Fluid Oxidizer Management Subsystems

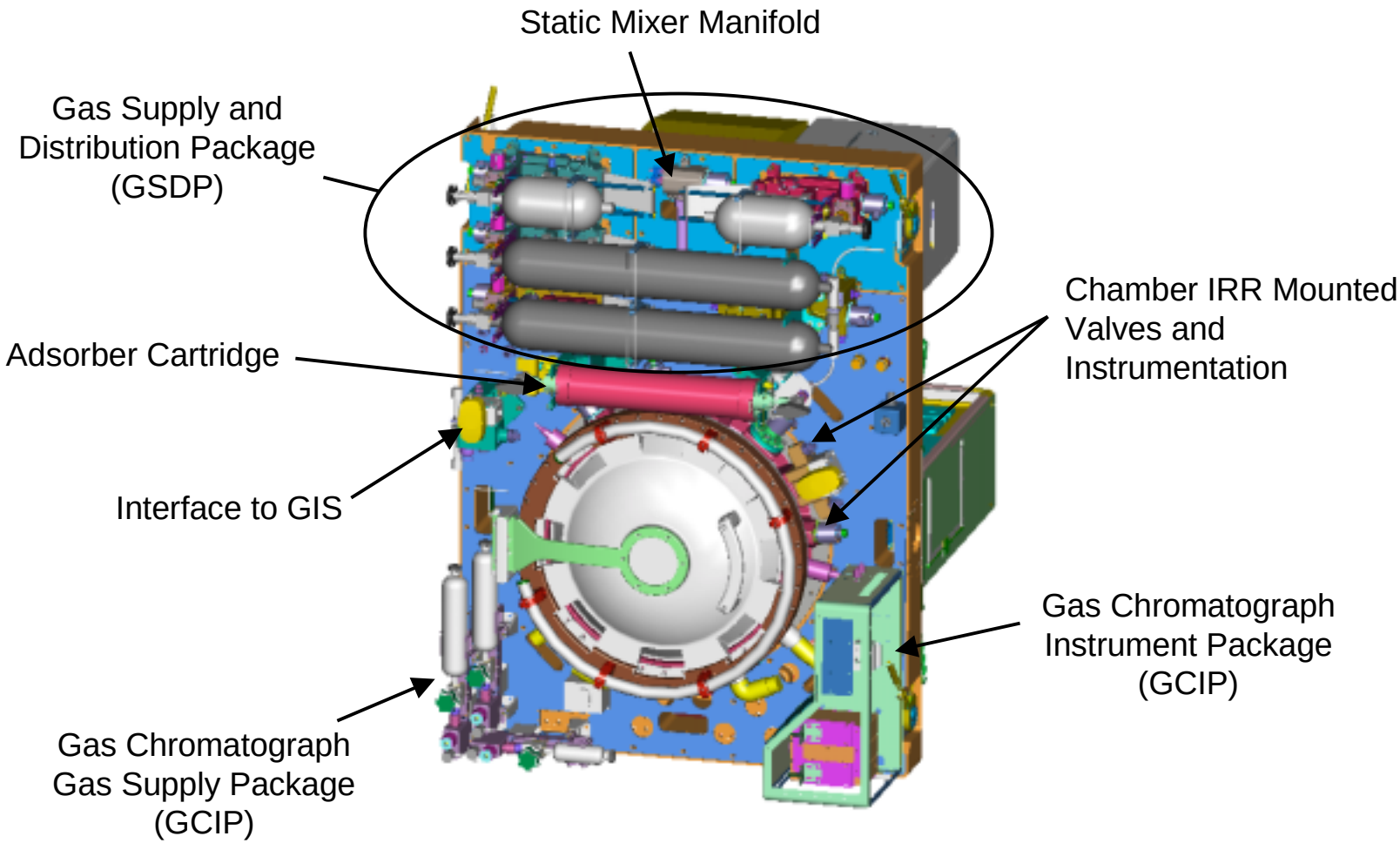
Fuel/Oxidizer Management Assembly (FOMA)

Functions

- Safe delivery of all gaseous fuels, diluents and oxidizers required to perform combustion experiment
- Deliver ISS Nitrogen to the combustion chamber through CIR GIS interface
- Sample the test chamber environment via a Gas Chromatograph
- Control the venting of chamber gases, at acceptable concentration levels, to the International Space Station Vacuum Exhaust System (ISS VES) through CIR GIS
- Commanded through the FOMA Control Unit (FCU)
- FCU functions are monitored by the IOP

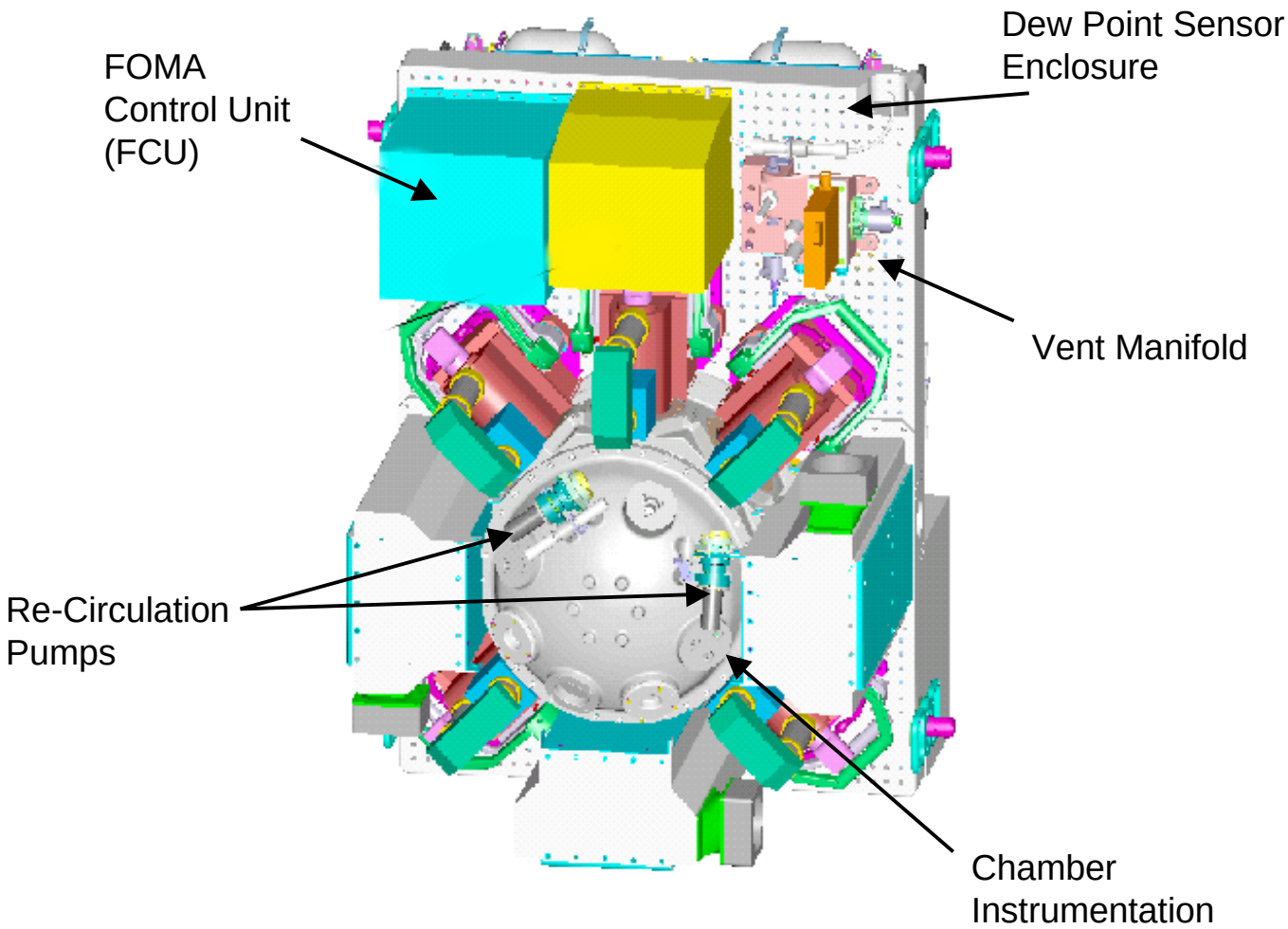
FOMA Component Locations

Optics Bench Front

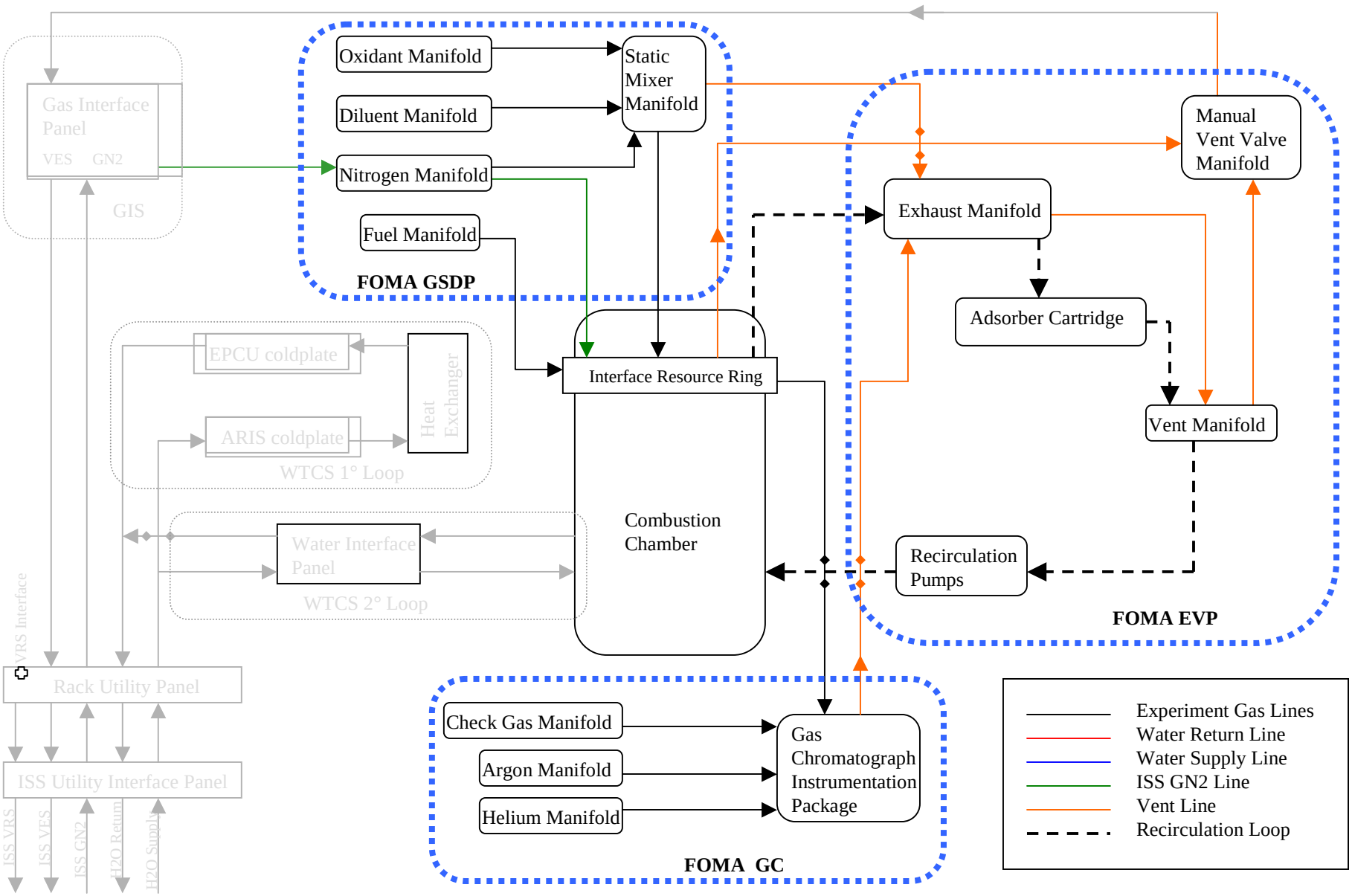


FOMA Component Locations

Optics Bench Rear



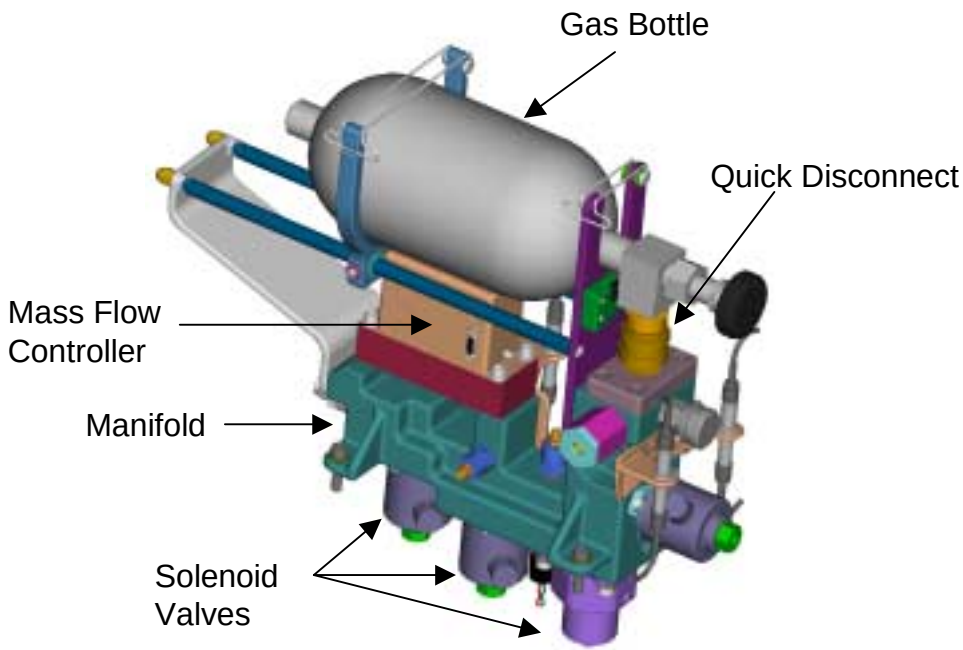
CIR Fluids System Diagram



FOMA Gas Delivery Package

Functions

- Supplies gaseous fuel, oxidizers and diluents to the combustion chamber
- Gas is delivered through 1.0, 2.25, and 3.8 liter bottles
- Oxidizers:
  - 1.0 liter up to 85% O2
  - 2.25 liter up to 50% O2
  - 3.8 liter up to 30% O2
- Quick disconnects used for easy attachment to manifolds
- Provides chamber environment via partial pressure or dynamic gas blending
- Maximum oxidizer flow rates
  - 30 slm per manifold
  - 90 slm total
- Maximum fuel flow rate 2 slm

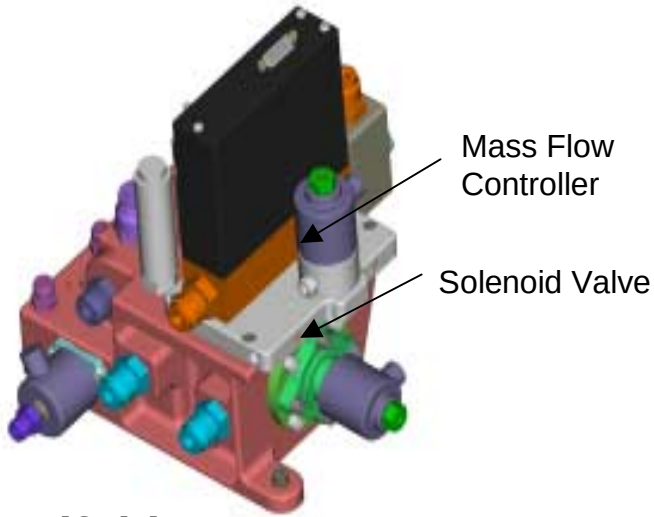


Fuel Manifold Assembly

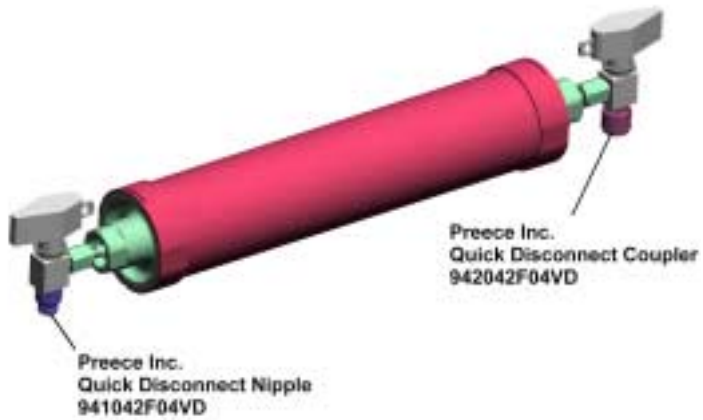
FOMA Exhaust Vent Package

Functions

- Removes unacceptable gases including water vapor, and particulates from the combustion event
- Provides the vent path to the ISS VES through an interface with the GIS
- Manifolds located on front and back of bench to direct flow
- Measures oxygen concentrations and dew point levels to assure ISS VES compliance
- Recirculation loop – combustion by-product clean-up
- Adsorber cartridges (2 sizes) are experiment dependant
- 2 - Magnetically coupled vane pumps provide re-circulation
- Mass flow controller used to regulate vented gas



Vent Manifold

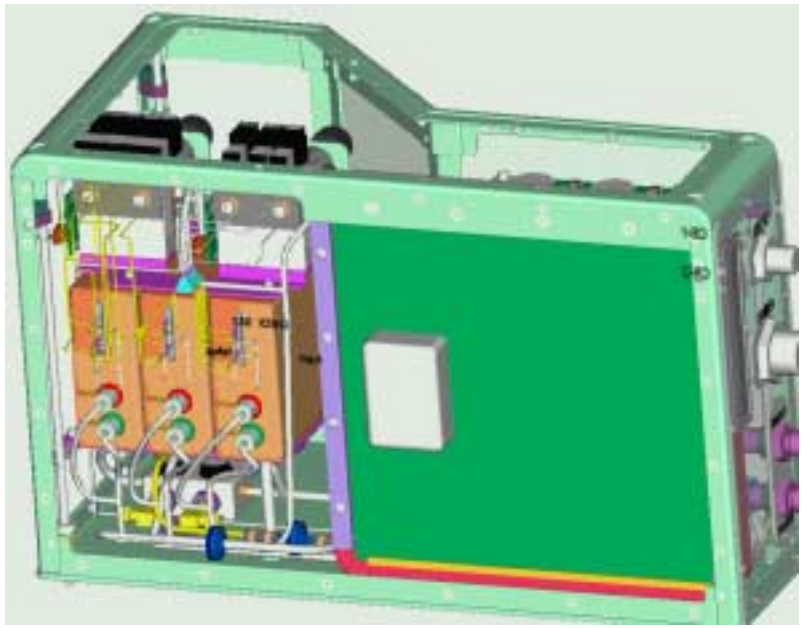


Adsorber Cartridge

FOMA Gas Chromatograph

Features

- Analyze combustion chamber environment
- Ability to sample close to combustion event
- Architecture based on high precision commercial micro-GC (GCIP)
- 3 column molecular sieve for detection of fixed gases, light hydro-carbons, and low molecular weight alcohols
- GCIP Stowed for Launch
- Carrier and check gas provided by stainless steel bottles located on front of optics bench (GCGSP)



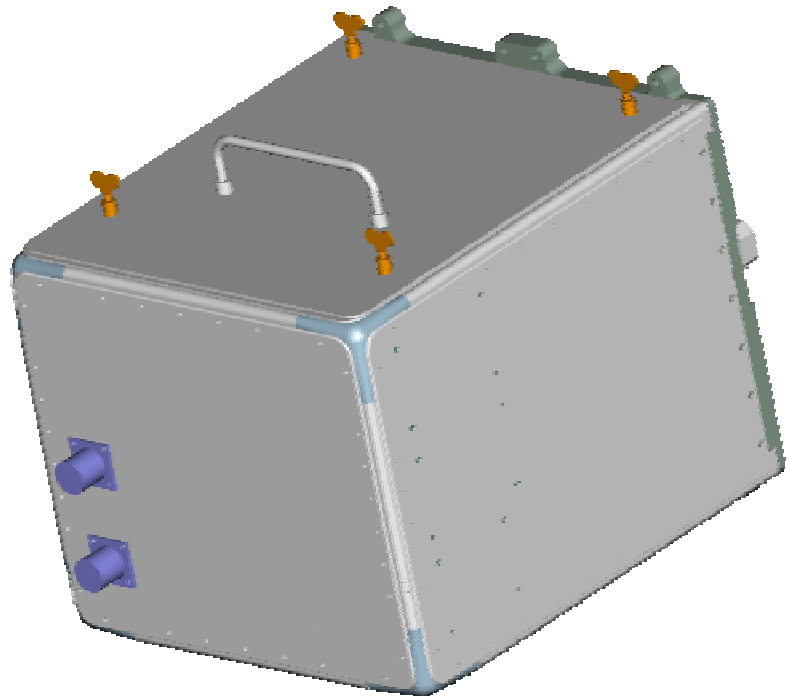
GCIP

FOMA Control Unit (FCU)

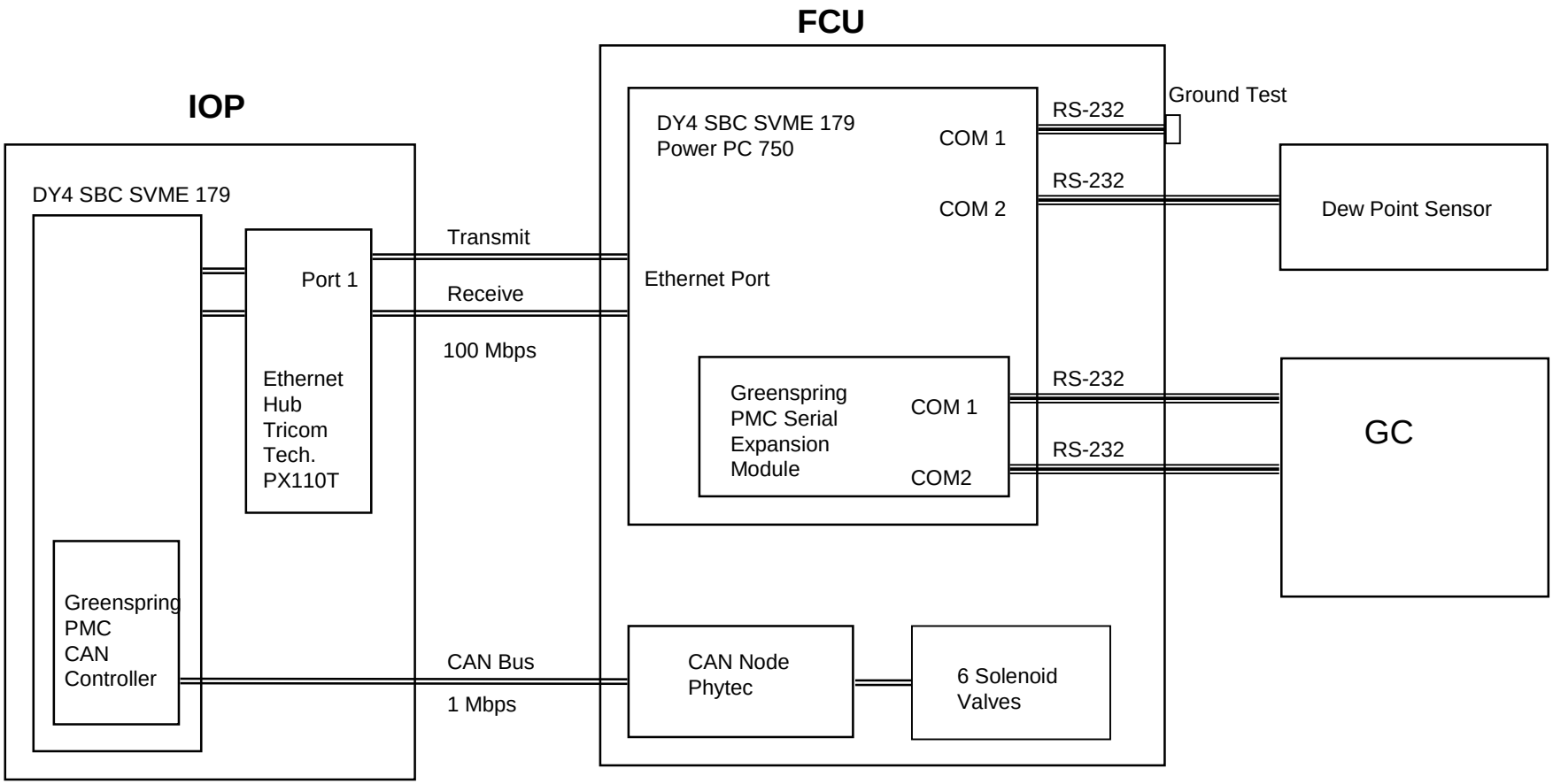
Features

FCU provides control of the following:

- Gas Blending
- Gas Flow
- Safely exhaust gases from the combustion chamber
- Monitor and store all pressures, temperatures and mass flow rates
- Gas Chromatograph
- Health and status to the IOP for transmittal to ground
- Commanding from IOP to the FCU via FLAP or Ground
- All VME cards can be removed/replaced on-orbit
- FCU stowed for launch



System Communication Architecture



FOMA Engineering Model Assembly and Testing

Component	Hydrostatic Test	Assembly	Helium Leak Test	Vibration Test (Qual Level)	Flow Characteristic
Nitrogen Manifold	CIR-TEST-0005	CIR-APR-0001	CIR-TEST-0006	SDL-TR98-42	Complete
Oxygen Manifold	CIR-TEST-0005	CIR-APR-0003	CIR-TEST-0006	N/A	Complete
Diluent Manifold	CIR-TEST-0005	CIR-APR-0004	CIR-TEST-0006	N/A	Complete
Fuel Manifold	CIR-TEST-0005	CIR-APR-0005	CIR-TEST-0006	SDL-TR00-11	Complete
Exhaust Manifold	CIR-TEST-0008	CIR-APR-EM0012	CIR-TEST-0011	SDL-TR99-39	Complete
Vent Manifold	CIR-TEST-0009	CIR-APR-EM0013	CIR-TEST-0012	SDL-TR00-15	Complete
Manual Vent Valve Manifold	CIR-TEST-0013	CIR-APR-EM0014	CIR-TEST-0013	SDL-TR99-39*	Complete
Static Mixer Manifold	CIR-TEST-0025	CIR-APR-EM0026	CIR-TEST-0026	N/A	Complete
Adsorber Cartridge (large)	CIR-TEST-0027	CIR-APR-EM-0017	CIR-TEST-0028	N/A	Complete
Adsorber Cartridge (small)	CIR-TEST-0029	CIR-APR-EM-0027	CIR-TEST-0030	N/A	Complete
GC GSP Manifolds – Argon/Helium	CIR-TEST-0019	CIR-APR-EM0023 CIR-APR-EM0024 (except press reg)	CIR-APR-EM0023A (he manifold only)	Report in work	N/A
GC GSP Manifolds – Check Gas	CIR-TEST-0020	CIR-APR-EM0025 (except press reg)	In Work	N/A	N/A
Re-Circulation Pumps	N/A	CIR-APR-0002	CIR-TPP-EM120	N/A	Complete

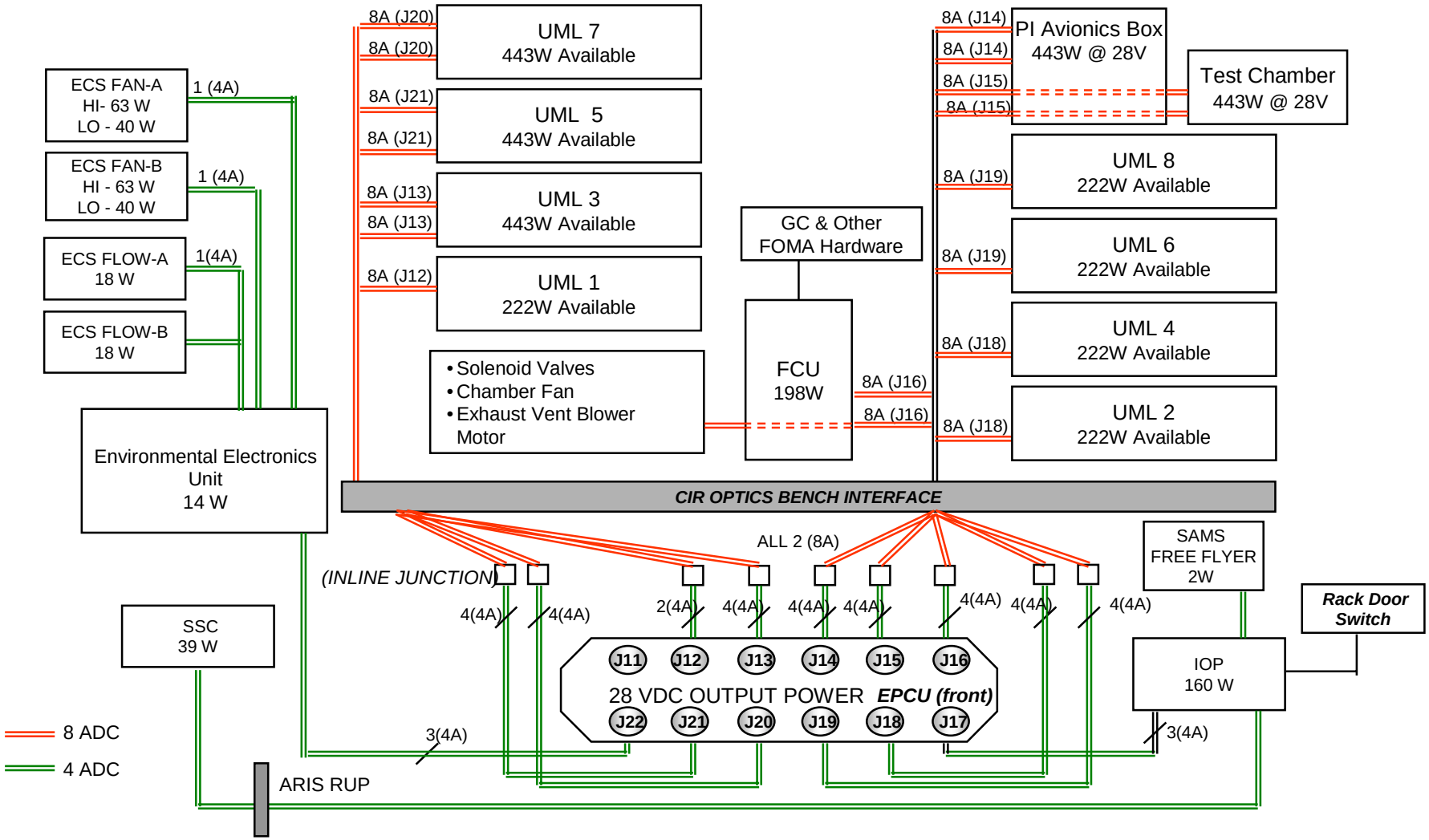
* Component failed first vibe test, was redesigned and successfully passed new vibe test

Summary of FOMA Development Testing
(April 1999 to Present)

- Combustion by-product testing and oxygen sensor testing for FEANICS
- Determine GSP regulator set-point for gas delivery to chamber
- Flow characterization tests to determine pressure drops and flow factors (Cv)
- Mass Flow Controller accuracy tests and calibration equations
- Oxygen Sensor performance testing
- Demonstrated oxygen bleed-in capability and documented results in report CIR-RPT-0038
- Tested bottle leak control method to meet ISS requirements
- Characterization tests to determine pressure switch set-points
- Performed re-circulation pump capability tests
- Demonstrated capability of separating control board from the Mass Flow Controllers, allowing remote mounting in the FCU
- Evaluated performance of Dew Point Sensor
- Investigated ways to increase the flow through capability of the FOMA, resulted in MFC/solenoid valve combination to assure 90 SLM exhaust flow
- Verified re-packaged commercial GC can function as required

CIR Electrical Power Subsystems

CIR Electrical System: 28 VDC Power Distribution Diagram



CIR Electrical System: Power System

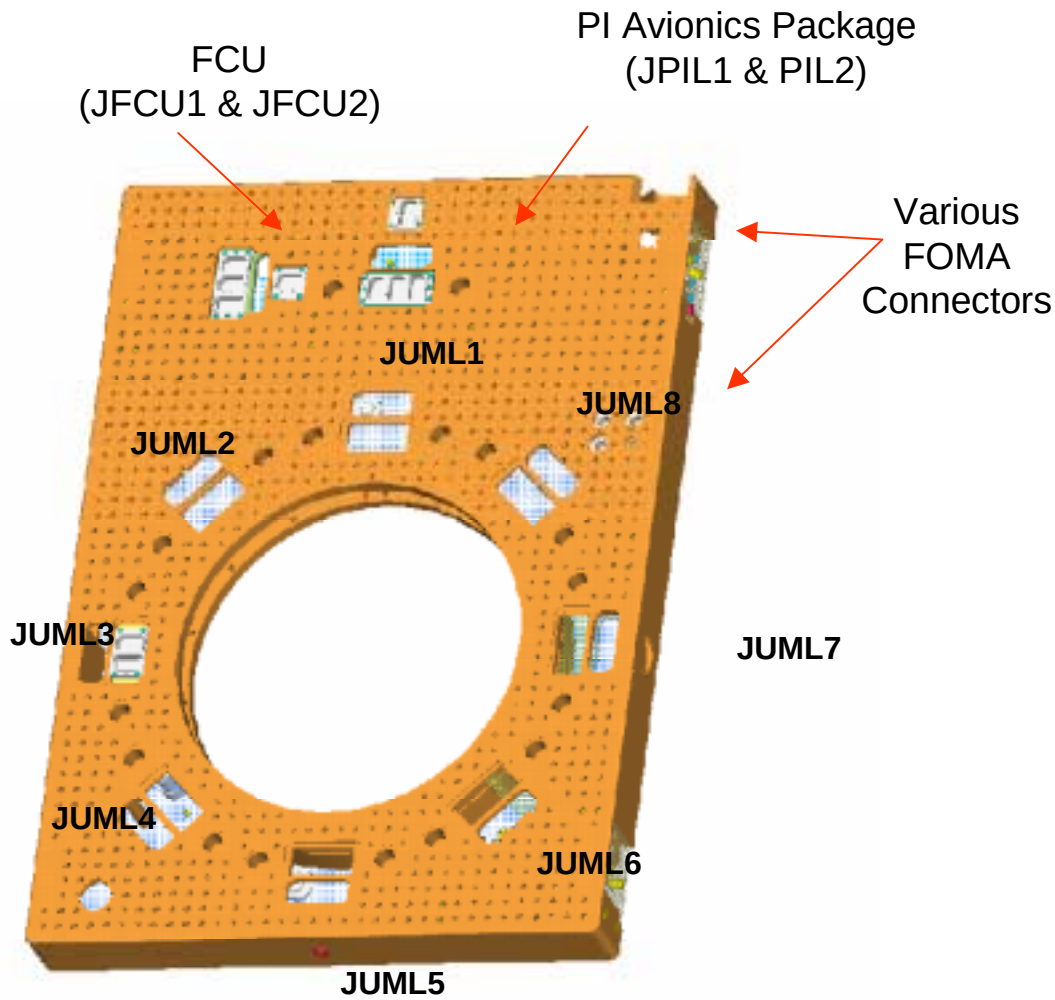
- CIR uses the common FCF power distribution for rack infrastructure components, e.g. ECS, IOP, SSC, ARIS, and FDSS.
- Paralleling of the EPCU 4 amp channels to create 8 amp channels occurs in the cable between the optics bench and the EPCU using Deutsch in-line junction terminals.
  - A quantity of 17, 28 VDC @ 8 Amp (222W) circuits from 10 EPCU connectors are routed to the optics bench. Paralleling the EPCU 4 amp channels occurs in the two power cables between the EPCU and optics bench.
    - 2 – 8A circuits for the PI Avionics location and test chamber
    - 2 – 8A circuits for the FCU, and UMLs 3, 5, and 7
    - 1 – 8A circuit for UMLs 1, 2, 4, 6, and 8
  - A quantity of 3, 120 VDC, 4 Amp circuits from the EPCU are routed to the left/rear side of the rack for PI use.

CIR Electrical System: Power System – Continued

- Changes from PDR:
  - UML 1 was changed from 2 – 8A circuits to a single 8A circuit.
  - The SSC cables will be routed through the RUP rather than the rack doors.
  - Connections to several power channels on the EPCU were rearranged to better accommodate cable routing.
  - Added access to 120VDC (3 – 4A channels) from the EPCU for PI use. A panel containing a single connector will be located on the rear left side of the rack. If the PI wishes to utilize the 120 VDC, a connection via a cable will be made between the PI Avionics package and this connector.

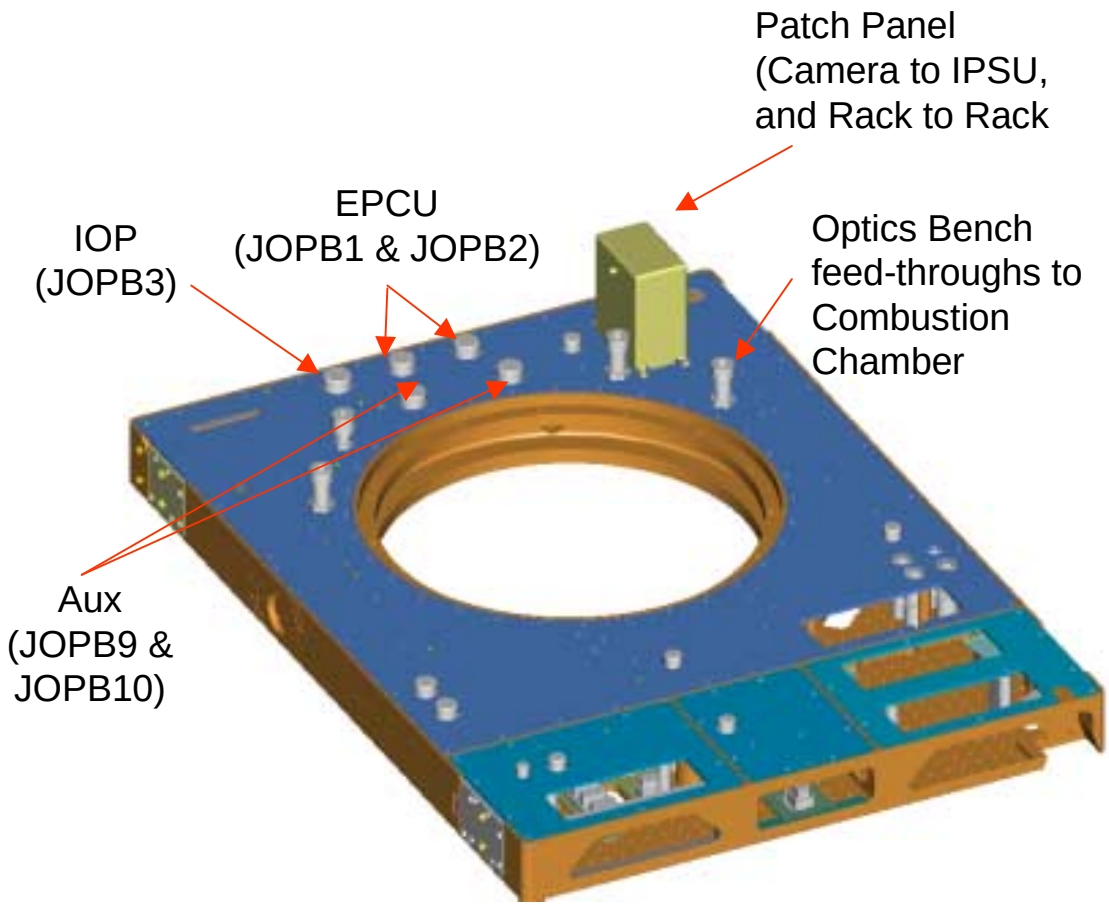
CIR Electrical System: Optics Bench Rear

- Universal Mating Location (JUML1 – JUML8) – Provides interface for power, ethernet, CAN bus, camera sync, digital and analog video to Diagnostic Packages and Image Processing Packages.
- FCU (JFCU1 & JFCU2) – Provides interface for power, ethernet, CAN bus, and FOMA data between FOMA elements and FCU.
- PI Avionics (JPIL1 & PIL2) – Provides interface for power, ethernet, CAN bus, camera sync, digital and analog video.
- AUX (JOPB9 & JOPB10) – Provides spare wires connected to UMLs for custom configurations.



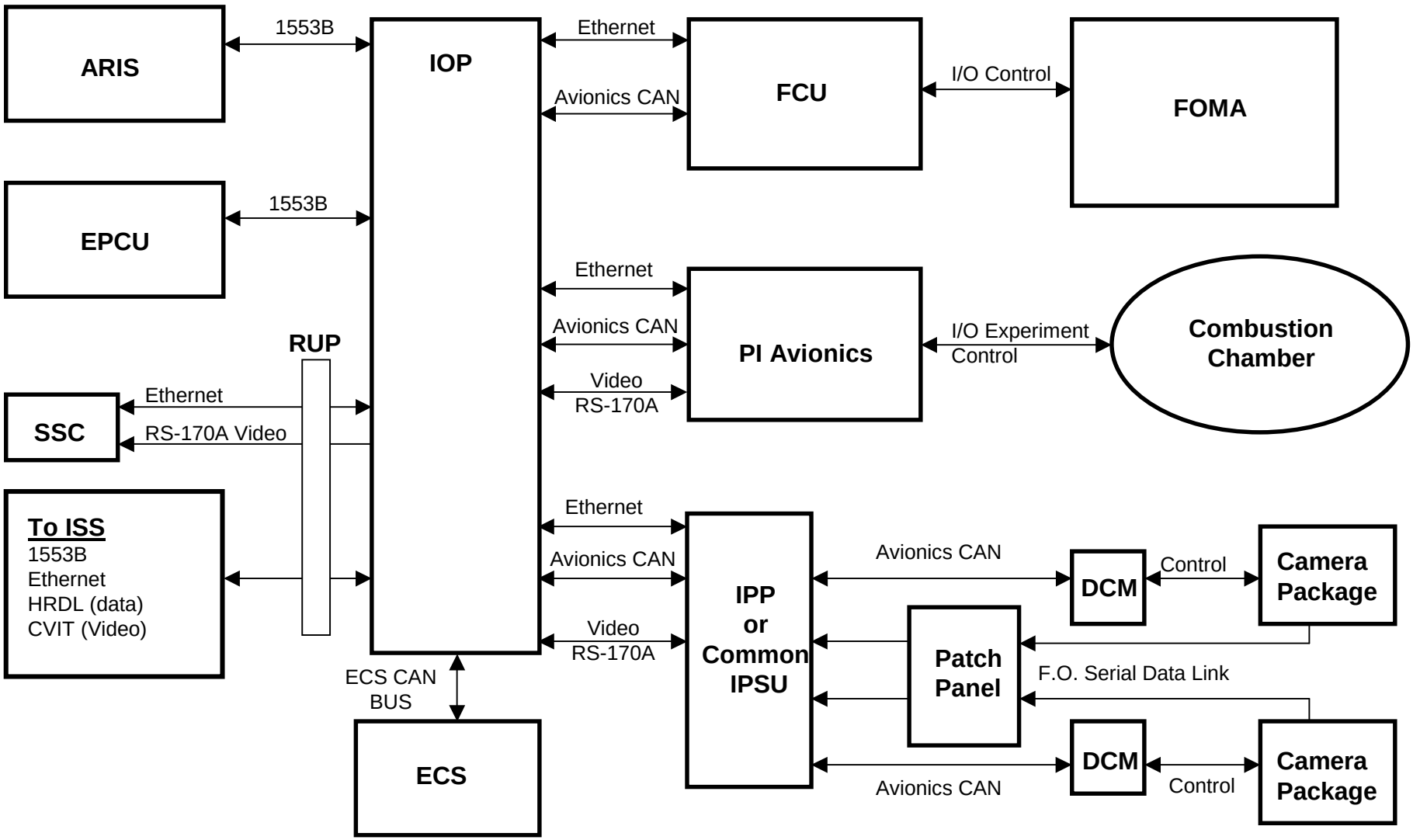
CIR Electrical System: Optics Bench Front

- EPCU (JOPB1 & JOPB2) – Provides interface for 28 VDC power between EPCU and UMLs.
- IOP (JOPB3) – Provides interface for ethernet, CAN bus, camera sync, analog video between UMLs, PI Location and IOP.
- Fiber Patch Panel – Allows patching of digital video signals between UMLs and between UMLs and adjacent racks.
- AUX (JOPB9 & JOPB10) – Provides access to spare wires connected to UMLs for custom configurations.



CIR Command and Data Subsystems

CIR Electrical System: Command and Data Handling System Diagram



CIR Electrical System: Data Services, Ethernet and Sync Bus

Ethernet (100 BaseT, 100 Mbits/Sec.)

- Command and control of the FCU, PI Avionics, and IPPs by the IOP
- Command and control of the IPSUs by the PI Avionics
- Image and science data transfer from the IPSUs and PI Avionics to the IOP
- Health and status data transfer from the PI Avionics to the IOP
- Software loads from IOP to the IPSUs, FCU, and PI Avionics

Sync Bus

- Synchronization of the avionics, diagnostic, and PI H/W from the IOP
- Programmable frequency range from 0 to 1000 Hz in increments of 5 Hz

CIR Electrical System: Data Services, CAN Bus, Video

Avionics CAN Bus (1 Mbit/Sec.)

- Health and status data transfer from avionics packages and diagnostic packages to the IOP
- Control of diagnostic packages by -IPSU
  - IPSU: HiRes IAM, HFR IAM and associate lens packages, Translation Stage, Gimbal Mirror via DCMs

ECS CAN BUS (1 Mbit/Sec.)

- Control of air thermal control system and water thermal control system via the IOP
- Health and status of the air and water systems sent to IOP

Analog Video: RS-170A

- Camera image data sent to the IOP from the IPSU for display on SSC, transmittal to SAR, and downlink via ISS
- Only one channel of analog video can be downlinked and/or stored on the ISS VTR at a time

Digital Video: Fiber

- Digital video data (on fiber) from IAM or PI camera sent to IPSU in CIR or SAR via rack-to-rack umbilical

CIR Electrical System: Data Services, Rack-to-Rack

F.O. Rack to Rack Signals

- Provide rack to rack image data at up to 2.5 Gbits/sec per fiber based on current transmitter/receiver design. Theoretically unlimited bandwidth as transmitter/receiver technology improves.
- 12 fibers CIR to SAR
- 12 fibers FIR to SAR
- Gigabit/sec Ethernet CIR to SAR ands FIR to SAR
- 1 Mbit/sec CAN bus between all FCF racks
- Sync bus between all FCF racks
- Analog video CIR to SAR and FIR to SAR

CIR Air Thermal Control System

Determination of Required Air Flow

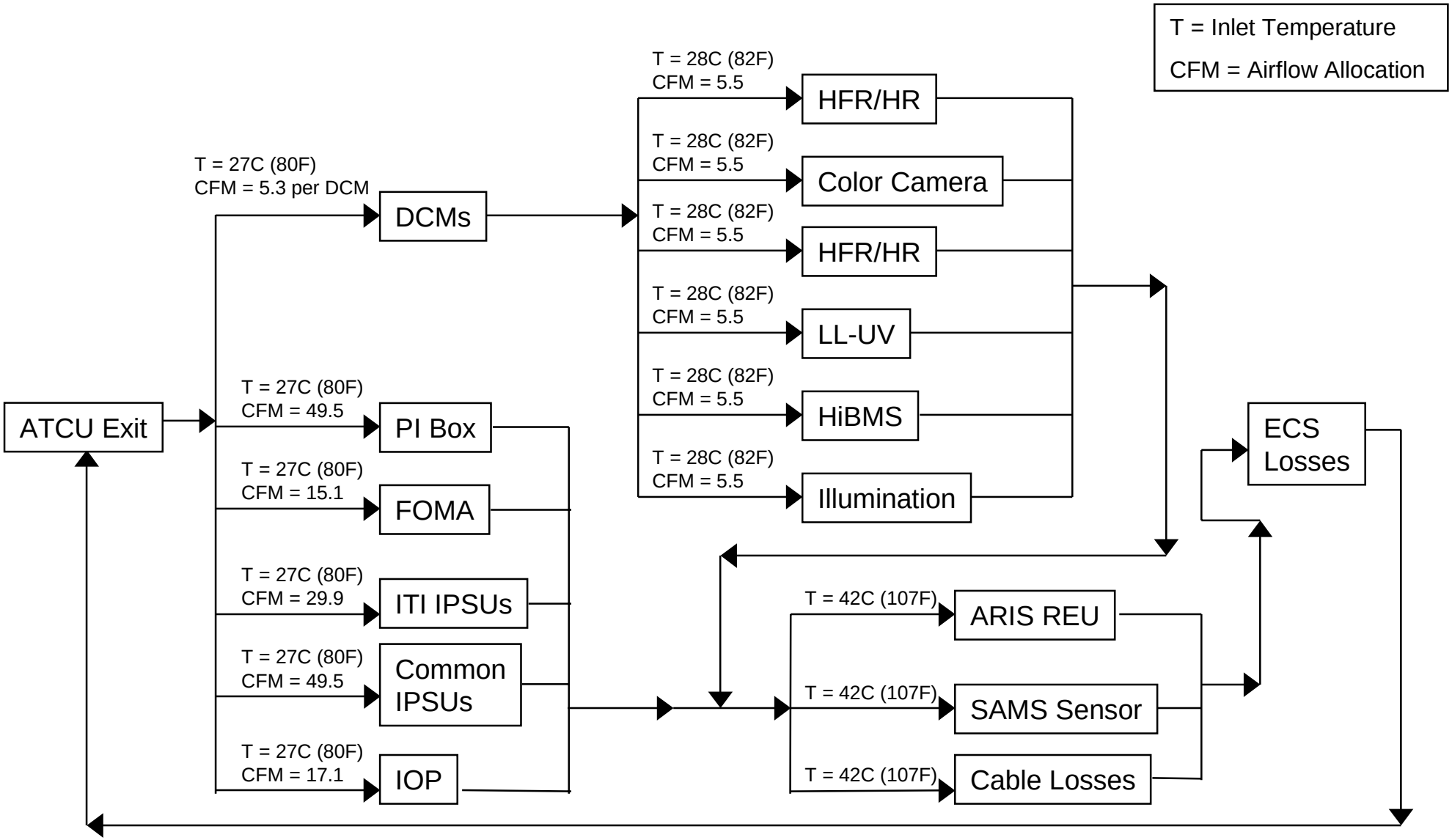
Applicable Science and System Requirements

- Reconfigurability of all facility hardware
- 450 watts of PI heat rejection through air, 500 watts through water

Amount of Air Required and Amount of Air Available

- Function of experiment configuration
- Function of rack heat dissipation
- Function of heat exchanger performance

Air Flow Distribution Model of DCE 2



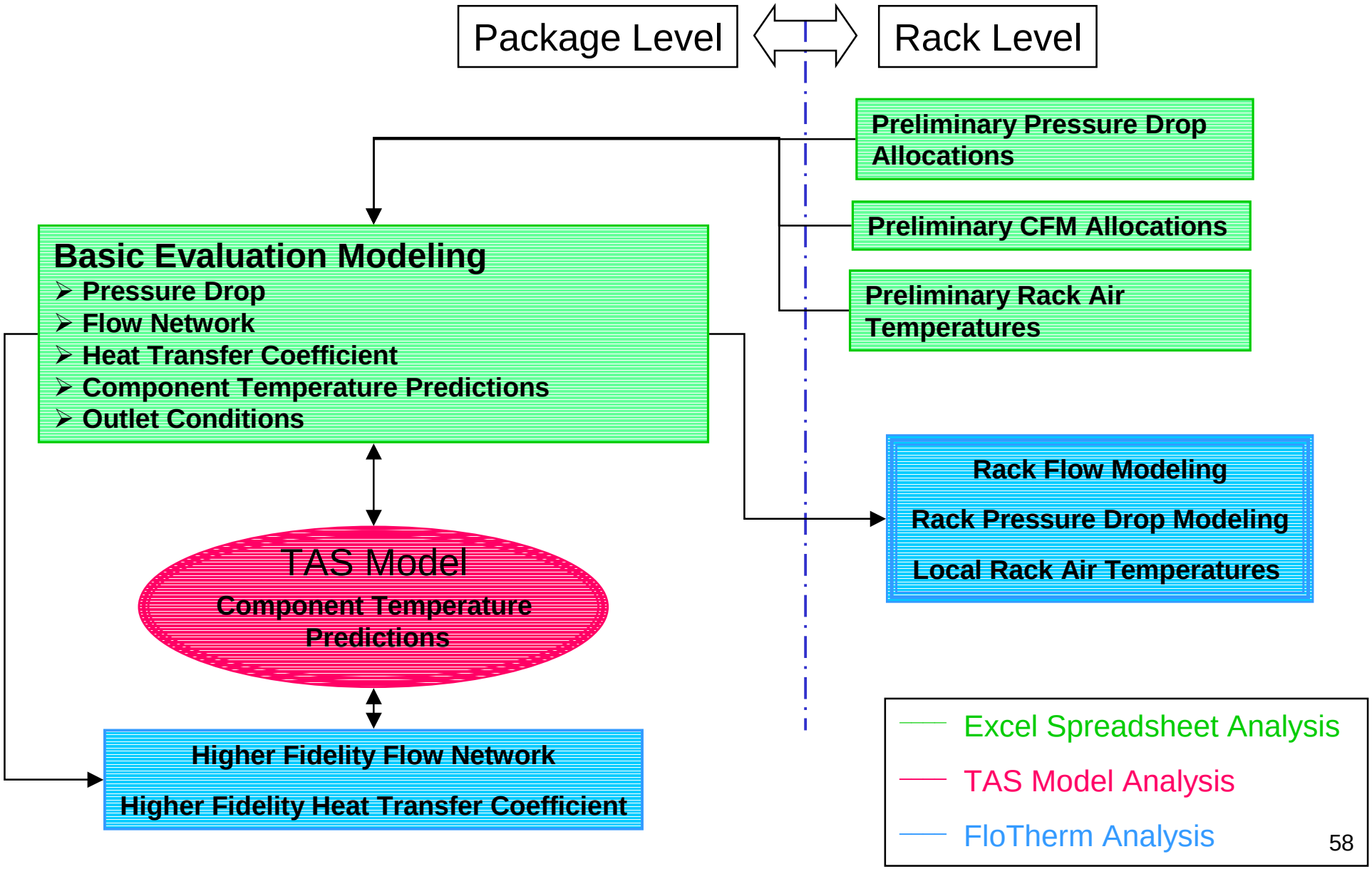
Air Flow Distribution DCE 2

CFM = Power X 0.11 CFM/Watt

Hardware	Power (Watts)	CFM Allocation
PI Box	450*	49.5
FCU	137	15.1
DCMs (5)	240	26.4
Color Camera	50	5.5
LL-UVs (2)	100	11.0
HiBMS	50	5.5
HFR/HR	50	5.5
Illumination Packages	36	4.0
IOP	155	17.1
Common IPSUs (3)	450	49.5
ITI IPSUs (2)	272	29.9
ECS Losses	166	18.3
SAMS Sensor	2	NA
ARIS	42	NA
Totals	**2200 Watts**	**237.3 CFM**

* Maximum load assumed based on System Specification

Thermal Analysis Overview



Status of Thermal Analysis

Package Level Thermal Analysis	Component Airflow Design	Volumetric Airflow Predicitons	Pressure Drop vs. Volumetric Flowrate	Component Temperature Limit	Component Power Dissipation Report	Alternate Flow Volumetric Airflow	Alternate Flow Pressure Drop vs.	Component Temperature	Loss of Cooling/Touch Temperature Analysis	Health and Status Monitoring
FOMA Control Unit (FCU)	✔	✔	✔	✔	✔	na	na	✔	✔	✔
Gas Chromatograph Instrumentation Package (GCIP)	✔	✔	✔	✔	✔	na	na	✔		
Door Thermal Verification Analysis										
ARIS Remote Electronics Unit Environment Analysis		na	na	na	na	na	na	na	na	na
Diagnostic Control Module (DCM)	✔	✔	✔	✔	✔	✔	✔	✔		
Image Acquisition Modules (IAM)	✔	✔	✔							
Illumination Source Diagnostic										
IPI IPSU	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Input/Output Processor (IOP)	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
ECS Electronics Unit (EEU)	✔	✔	✔	✔	✔					

Status of Thermal Analysis

System Level Analysis To Be Performed

- Transient System Power Consumption for Basis Experiment Test Points
  - Predict air temperature at outlet of heat exchanger
  - Calculate and provide appropriate inlet conditions for package level thermal analysis
- Rack Level Flow Analysis
  - Predict air flow paths in rack volumes
  - Provide appropriate flow velocity and heat transfer conditions for package level thermal analysis

Thermal Analysis Summary

- All package thermal analyses were conducted assuming a heat exchanger outlet temperature of 27°C (80°F).
- 27°C is associated with a Treitler heat exchanger load of 2400 W.
- At this heat exchanger outlet temperature, preliminary analyses have indicated no violation of component temperature limits.

CIR Diagnostics

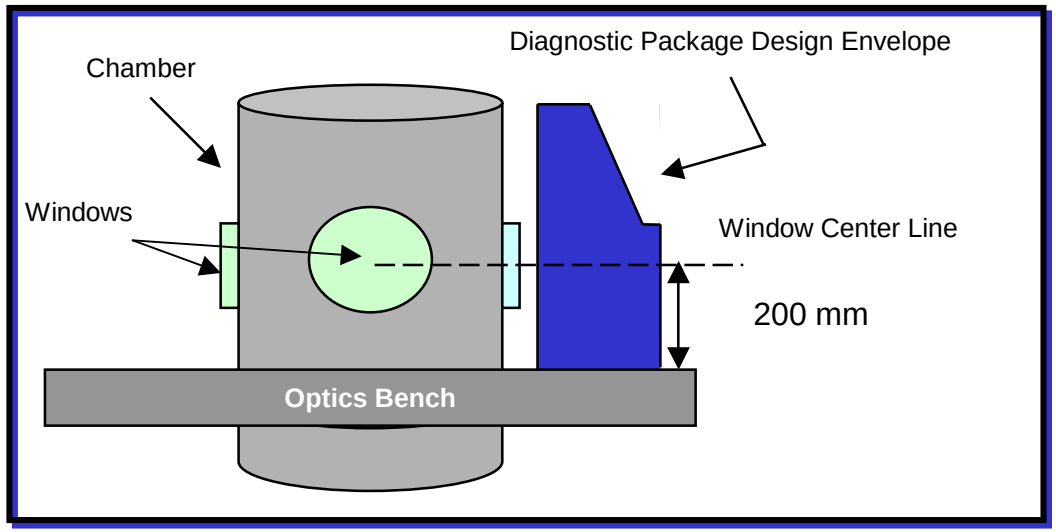
CIR Diagnostic Package Overview

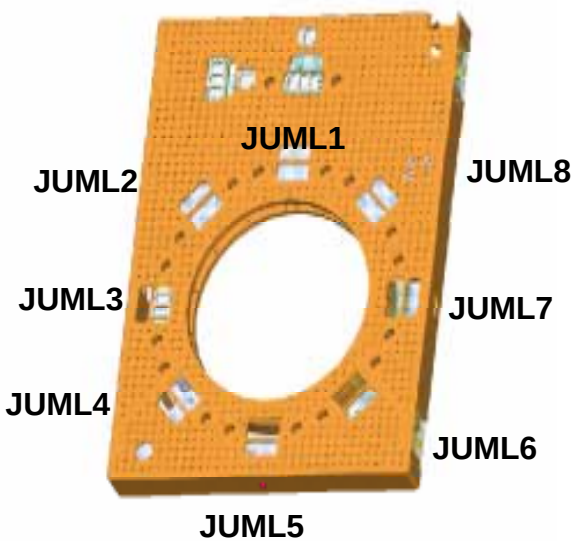
Description

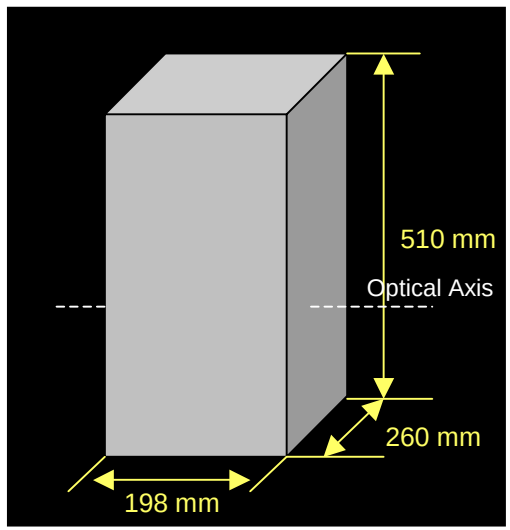
- Seven diagnostic packages are planned:
  - High Bit Depth/Multispectral Imaging Package (HiBMs)
  - High Frame Rate/High Resolution Package (HFR/HR)
  - Color Package
  - Low Light Level-UV Package
  - Low Light Level-IR Package
  - Mid-IR Package
  - Illumination Package
- Mounted on the Optics Bench using common interfaces (UMLs) for science versatility
  - Blind connections (power, control, avionics) to eliminate manual cable reconfiguration
  - Diagnostics re-configuration requires Optics Bench fold down
  - Height of optical axis centerline from Optics Bench: 20 cm
- Design approach emphasizes electronic and mechanical packaging modularity for operational flexibility and maintainability
  - On- orbit change-out to support future growth
  - Designed for performance and technology upgrade at module level
  - Motor control and power conversion electronics are housed within the base of the package (DCM)
  - Optical Modules using standardized optical interfaces (referred to as the flange mounts)
- Digital imaging technology implemented to collect and store data of the highest fidelity possible
  - An optical fiber data link is used between the digital imaging packages and the image processors
  - Real time video is provided for experiment status monitoring purposes
- Packages contain embedded software for closed loop operations

Diagnostics Architecture

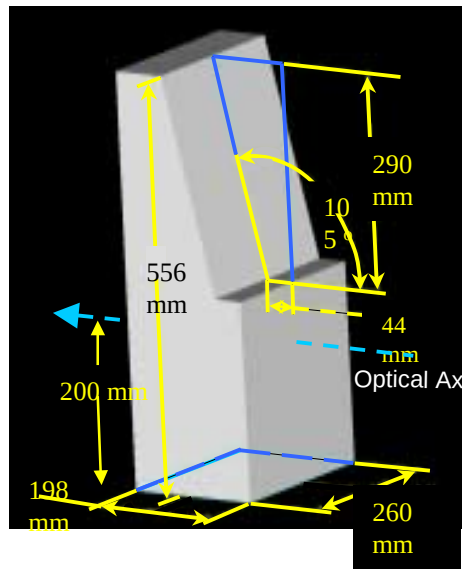
- Packages are located on the Optics Bench at UML sites
- All Diagnostics configuration must meet the physical envelopes defined to fit within the CIR







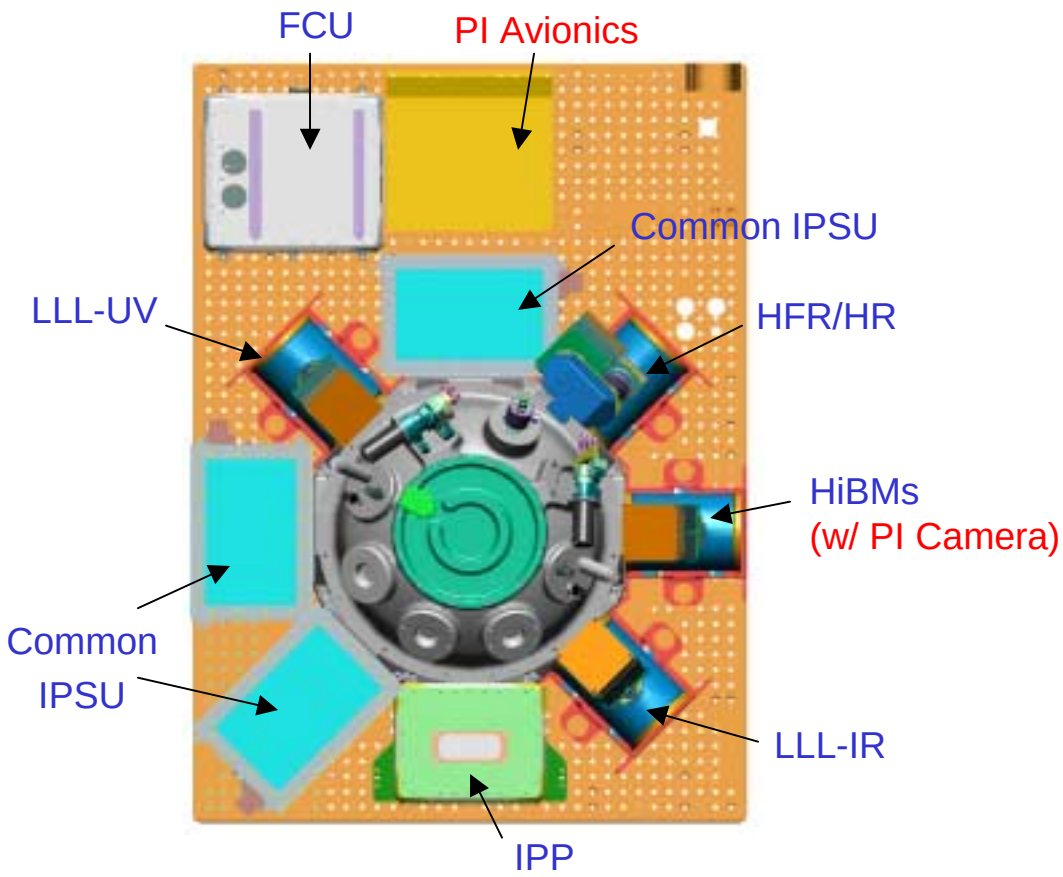
Package envelope for UML 3, 5 and 7

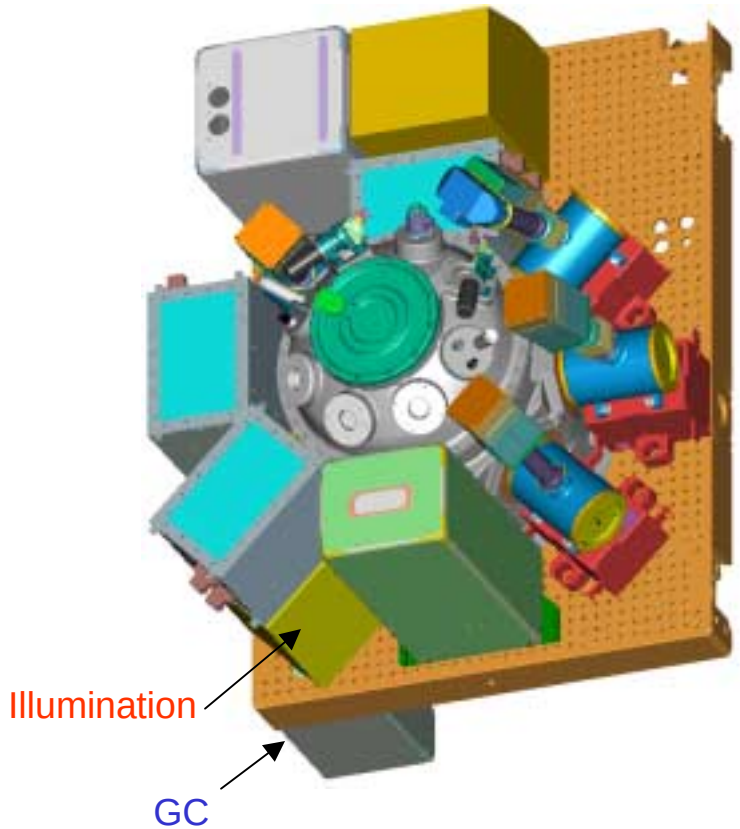


Package envelope for UML 1, 2, 4, 6, and 8

Experiment c6 – Droplet Combustion

Example Diagnostic Package Layout

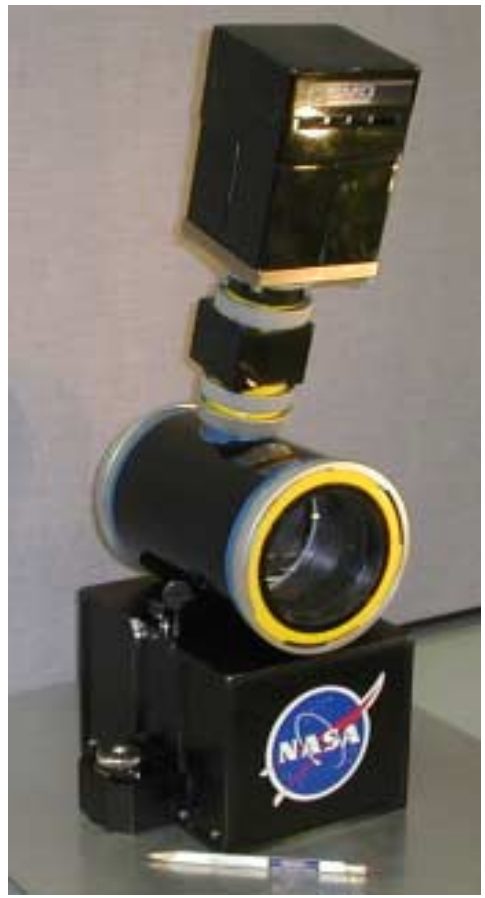




HiBMs Diagnostic Package

Specifications/Features

- Optical system
  - Manual aperture adjustment
  - Numerical Aperture: 0.005 to 0.02
  - Focus 208 mm from inside surface of chamber window
  - Field of View: 50 mm square or 80 mm diameter
  - Resolution: 10 lp/mm maximum (0.05 mm)
- Liquid Crystal Tunable Filter (LCTF)
  - 10 nm FWHM bandpass
  - 650-1050 nm spectral range
  - 1 nm spectral resolution
  - 100 ms switching time between states
  - May be replaced with a PI provided RGB filter for field sequential color or removed for broad spectrum imaging
- 12 bit dynamic range
- Programmable frame rate (7.5, 15 or 30 fps)
- Programmable exposure time



HFR/HR Diagnostic Package

Specifications/Features

- Automated Tracking - Capable of steering a 9 x9 mm Instantaneous FOV (IFOV) over a total 46 mm dia. total FOV truncated to 37 mm horizontally & vertically
- 10mm/ s maximum tracking speed
- Automated focus over 30 mm object depth; 5mm/s focus speed; telecentric
- Package may be programmed to sequentially operate in the 2 alternate modes
  - High Resolution Mode: 1024x1024 pixels at programmable frame rate of 7.5, 15, or 30 fps
  - High Frame Rate Mode: 512x512 pixels at programmable frame rate of 60 or 110 fps
- Resolution is 20 lp/mm at 50% contrast in HR mode (0.009 mm at Nyquist limit)
- Event trigger capability
- Provides I/F for LCTF

Color Diagnostic Package

Specifications/Features

- Field of view: 90 to 350 mm square
- Resolution: 2.8 to 0.7 lp/mm at Nyquist limit (0.18 mm maximum resolution)
- Motorized modular zoom design with 2X range and auto- iris
  - Zoom can be removed for future upgrades
  - Motorized focus and iris
- Two Objective Optics Modules; wide angle module is 2x FOV of narrow angle module
- Frame Rate: 30 fps
- 20 lux illumination required for saturation
  - Gain may be programmed or set in the AUTO mode
- Automatic and manual white balance control
- Backlight correction
- Maximum shutter speed: 0.1 ms
- Spectral range: 400-700 nm

LLL-UV Diagnostic Package

Specifications/Features

- Optical System
  - FOV: 42 and 100 mm square
  - Resolution (binned): wide field 1.8 lp/mm (0.28 mm); narrow field 44.3 lp/mm (0.12 mm)
  - Provision for manually inserted filters
    - Providing 310 nm filter with a 10 nm FWHM bandwidth
  - Manual iris and focus
- Camera
  - Spectral range: 220-850 nm
  - Sensitivity: 5x10E-8 ft. candles binned
  - Gen II Intensifier
  - Gated
  - Frame rate: to 60 fps

LLL-IR Diagnostic Package

Specifications/ Features

- Optical System Parameters
  - FOV: 45 to 180 mm square
  - 2 x motorized zoom
  - Two Objective Optics Modules; wide angle module is 2x FOV of narrow angle module
  - Resolution (binned): wide field 1.1 lp/mm (0.45 mm); narrow field 4.3 lp/mm (0.17 mm)
  - Motorized focus and iris
  - Accepts standard bandpass filters
- Camera
  - 400-900 nm (IR shifted)
  - Sensitivity: 5 x 10E-8 ft-candles binned
  - Gen III Ultra Intensifier

Mid-IR Diagnostic Package

Specifications/Features

- Optical System
  - FOV: 18.3 x 13.8 cm
  - Resolution: 0.9 lp/mm (0.55 mm)
- Camera
  - Frame Rate: up to 60 fps
  - Spectral range: 3000-5000 nm
  - Chamber windows are transmissive across the full sensitivity spectrum
  - Temperature Range: -10C to 450C (up to 1500C if filter is used)
  - Minimum Resolvable Temperature Difference: 0. 2 C @ 0.9 lp/ mm
  - Automatic and PI defined calibration options (2, 3 or 4 point correction)
  - Provides interfaces for manually inserted filters or filter wheel

Illumination Package

Specifications/ Features

- Optical System
  - 80 mm diameter collimated beam
  - Source is software selectable
  - Tungsten Halogen Source
    - 0.6 lumens/ mm2
    - 50% illumination field uniformity
    - 3000 K color temperature
    - 2% stability
    - 7.6 milliradians divergence
- Diffuse Laser Diode Source
  - 10 mW coupled power minimum; programmable level
  - 60% Illumination field uniformity
  - Peak Wavelength: between 660 and 690 nm
  - Spectral Bandwidth: 7 nm maximum at 50% points
  - Can be synchronized with the imaging packages

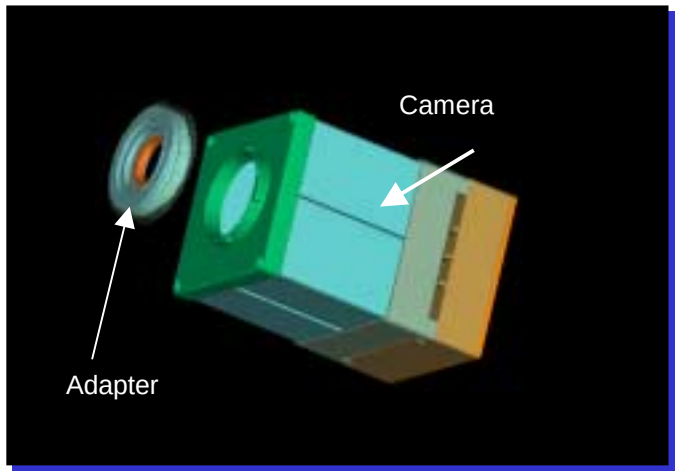
Combustion Diagnostic Capability Summary

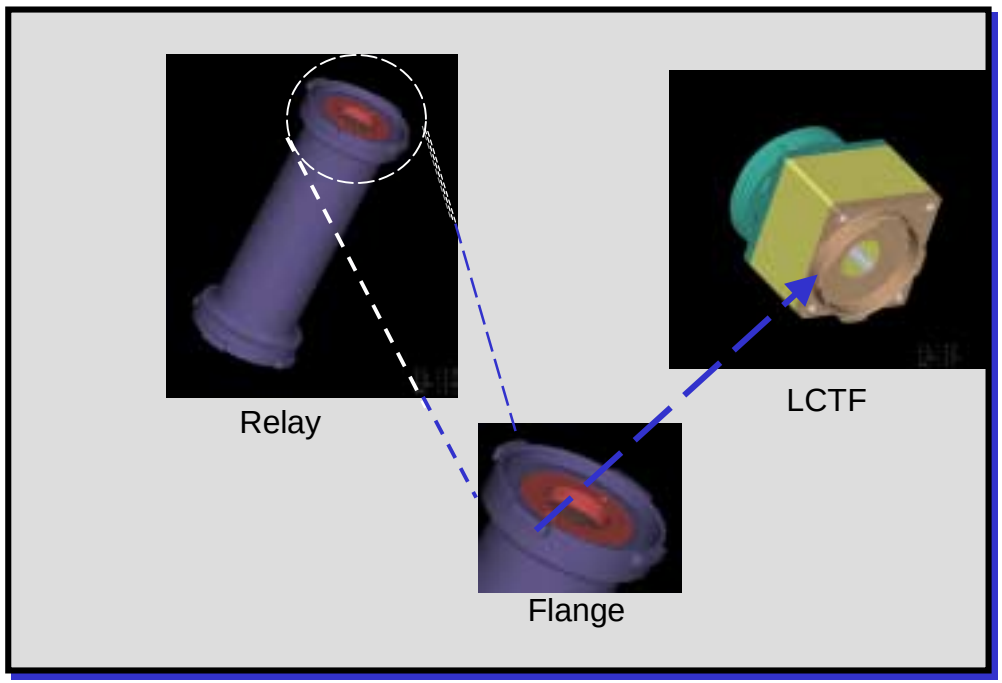
Diagnostic Package	Imaging Physics	Derived Applications	PI Utilization	Pixels	Field of View	Resolution	Bit Depth (all digital)	Run Time	Frame Rate	Minimum Exposure Time	Spectrum	Sensitivity	Features
			note 7	note 2	mm	lp/mm Note 4	bits	minutes	frames/sec	milliseconds	nm	object radiance	note 8
HiBMs	Bkgrnd lum absorption Near IR Emissions Density Gradients	Soot Volume Fraction Soot Temperature Shadowgraph	c3, c6, c7 c8, c11	1024 or Bin 512	50 & 80 dia. Telecentric	10 & 5.0 5 & 2.5	12	20 m @ 15 fps	15 Note 1	1	650-1000 Note 5	N/a 1200K – 2000K 0.8K/mm	Manual iris
HFR/HR	Short Exposure FOV Pointing	High Frame Rate High Resolution	c6, c8	Bin 512 1024	9 square Note 3 Telecentric	12 @ 50% mod. 20 @ 50% mod.	8 (12 avail. if binning)	20 m @ 110 fps 20 m @ 30 fps	110 Note 1 30 Note 1	1	520-880 Note 6	600 lux	Centroid Tracking Event Trigger Autofocus
Color	Visible Spectrum	Configuration Verification	All (except c9)	512x512	90 – 350 sq. Zoom	2.8 – 0.7	28	25 m @ 30 fps	30	0.1	400-700	20 lux @ f/3	Auto-iris Motorized focus
Low Light Level - UV	Short Wave Intensified	OH Emissions	c1, c2, c3, c4, c6, c8, c9, c10	Bin 512 1024	42 & 100 sq.	4.3 & 1.8 6.7 &2.8	8	40 m @ 60 fps 20 m @ 30 fps	60 30	10 ns	220-850	5x10E-8 ft-candle 1x10E-7 ft-candle	Manual iris Manual focus
Low Light Level - IR	Long Wave Intensified	H2O Emissions	c1,c2, c3, c5, c6, c7, c9, c10, c11	Bin 512 1024	45 – 180 sq. Zoom	4.3 – 1.1 6.8-1.7	8	40 m @ 60 fps 20 m @ 30 fps	60 30	10 ns	400-900	5x10E-8 ft-candle 1x10E-7 ft-candle	Auto-iris Motorized focus
MID-IR	Thermal	Absorption Lines Temperature	c3, c4, c8, c9 c10, c11	320x244	183x138	0.9	12	200 m @ 60 fps	60	1	3000-5000	263K to 1773K	
Illumination	W-Halogen Noncoherent Coherent	Calibration Bkgrnd Illum Interferometry	c3, c5, c6, c7, c8, c11	N/A	80 dia. Collimated	N/A	N/A	N/A	N/A	N/A	3000K 675	5 mw output	Illumination Source Selectable

Note 1: External sync: can do time exposures.
Note 2: Binning, sub-area recording and auto-gain/saturation protection are available in the image acquisition system.
Note 3: This FOV is steerable within a 46 mm diameter field.
Note 4: At Nyquist limit.
Note 5: 10 nm bandpass; tunable to 1 nm. Allow 100 msec for switching. Removable for broadband operation or replaceable with RGB filter or 400-720 nm tunable filter.
Note 6: Provision for installation of tunable filters for multispectral or field sequential color imaging.
Note 7: PI Codes: c1 – Bahadori; c2 – Ronney; c3 – Spread Across Liquids; c4 – Altenkirch; c5 – Smoldering Combustion; c6 – Williams; c7 – Faeth; c8 – Choi; c9 – Cool Flames; c10 – Tien; c11 – TITSI. Underlined: not in SRD.
Note 8: Autofocus is available with applicable PI software.

Diagnostics Modules

- Each diagnostic module is mechanically interfaced by flange.
- A four tap design is used to align male and female portions. A twist of a lock ring ensures engagement of components.





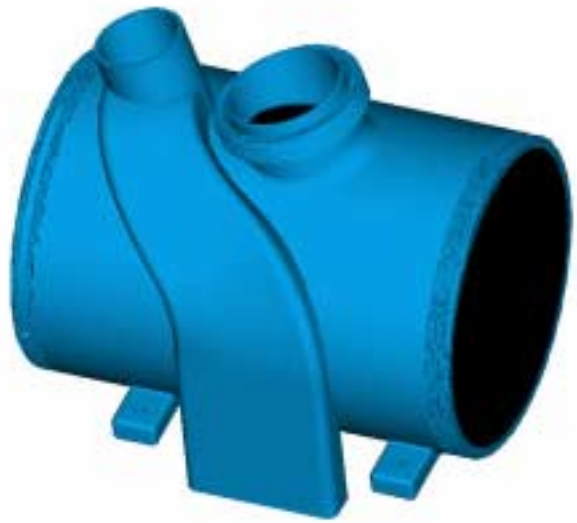
- The CIR also provides a flange to C-Mount adapter.
- This module allows the interfacing of CIR provided cameras with standard commercial lenses.

Optics Housing Module

Features

Core interface assembly for the Diagnostic Packages

- Kinematic interface to the DCM
- Three-flange interfaces
  - Objective Optics Module
  - Mirror Module (Fixed or Pointing)
- Four-flange interfaces
  - Relay Optics Module
  - Filter Module
- Provides air duct for IAM/DCM link
- Blind electrical connector interface for
- Pointing Mirror and Objective Optics Modules
- Castings for main body component

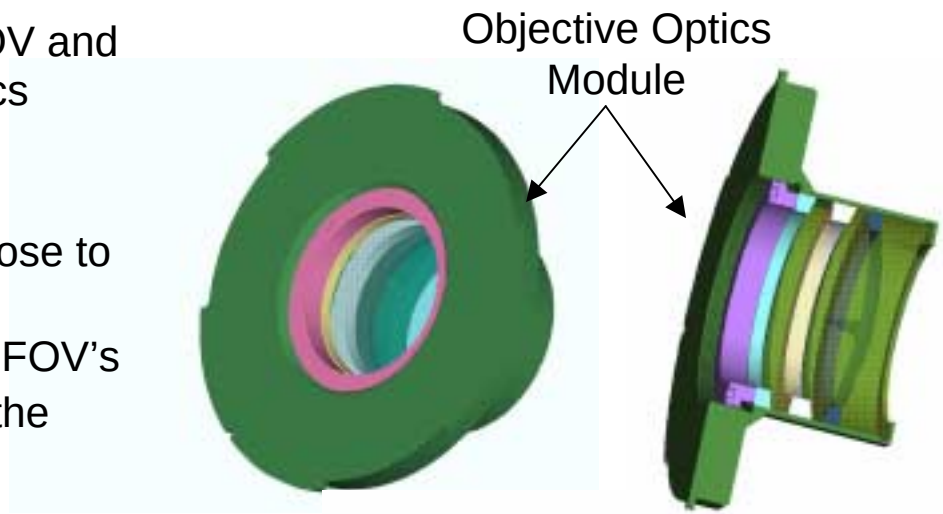


Objective & Relay Optics Modules

Features

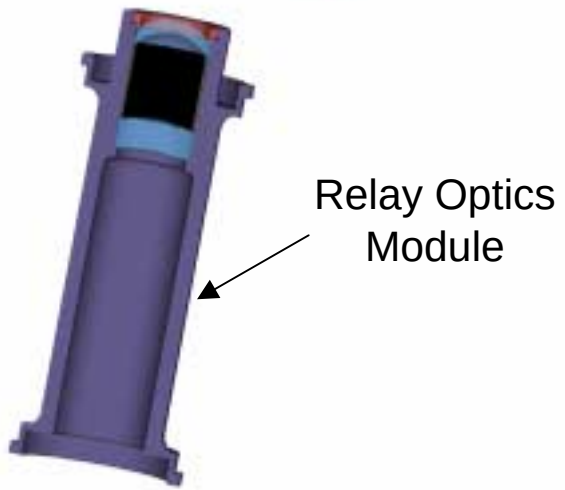
Objective Optics Modules

- Purpose: Collect light from the object plane FOV and form an intermediate image for the Relay Optics Module
- Generally large in diameter
- Attaches to the Optics Housing Module very close to the combustion chamber window
- Can be manually changed to achieve different FOV's
- Use the Three-Flange Mount to interface with the Optics Housing Module



Relay Optics Modules

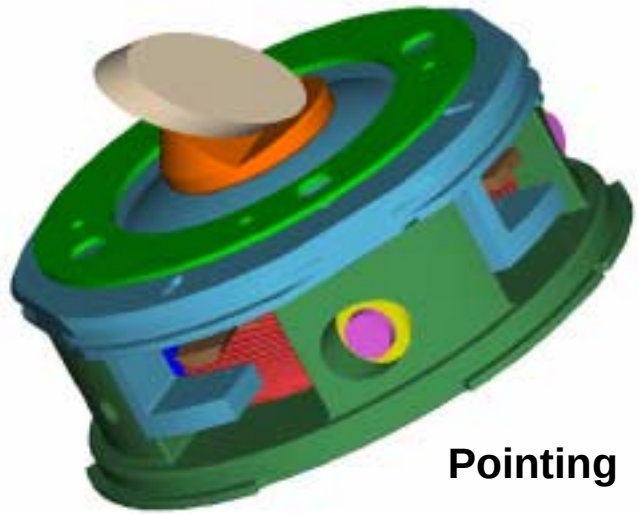
- Purpose: Collect the intermediate image formed by the Objective Optics Module and relay it "downstream" to the camera CCD array
- Located between the IAM and the exit port of the Optics Housing Module
- Fixed focal length and 2X motorized zoom designs
- Typically includes provision for a manually inserted spectral bandpass filter
- Use the Four-Flange Mount to interface with other modules



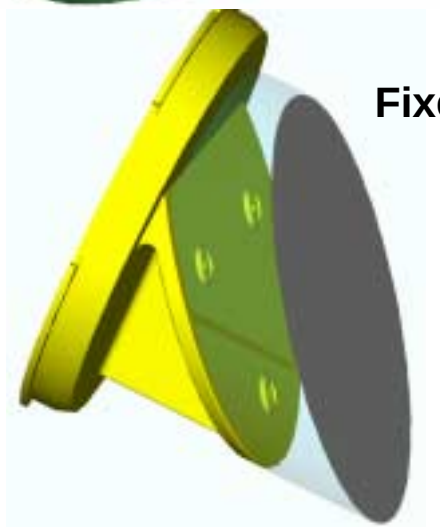
Mirror Modules

Features

- Used to fold light path for the 75° angle between the axis of the Objective Optics Module and the axis of the Relay Optics Module
- Modules are interfaced with the Optics Housing Module with a Three-Flange Mount
- Fixed Mirror Modules are used in all Diagnostic Packages except HFR/HR
- Pointing Mirror Module is used in HFR/HR only
  - Electronically controlled using object tracking and control software contained in the IPSU
  - Mechanical design sets the mirror on a “virtual gimbal”
  - Mirror will be driven by two independently controlled servo motors with encoders
  - End limit and home sensors are used to prevent over-travel of the motors and to reset the encoder count for mirror positional accuracy
  - Blind connection to the Optics Housing Module



Pointing

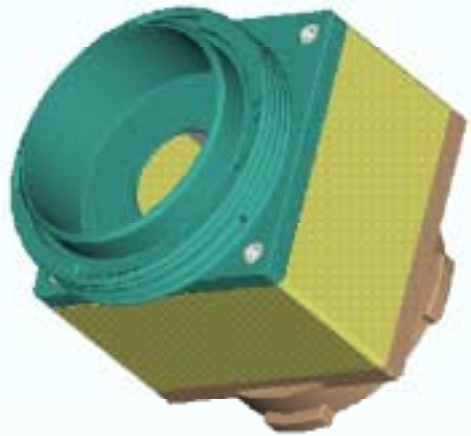


Fixed

Filter Module

Features

- LCTF Module is an electronically controlled spectral band pass filter
  - Initially used in the HiBMs Package for Soot Volume Fraction and Soot Temperature measurements
  - Interfaces to a dedicated PCB and is controlled by software contained in the DCM
  - Selectable wavelength range is between 650 nm and 1050 nm
  - Band pass at each selected wavelength is 10 nm
  - Transmission varies with wavelength: 14% at 676 nm
- Filter Compensator Module is used in place of the LCTF
  - Maintains the proper optical path length
  - Removable aperture stop assembly
  - Initially used in the HFR/HR Package



LCTF

Compensator

Focus Prism Module Assembly

Features

- Supports 30 mm of focus depth in object space
- Object space depth rate: 5 mm/sec maximum
- Visible spectrum light transmission
- Clear aperture: 14 mm square
- Electrical interface is with a driver board in the DCM via a 15 pin Airborn connector
- Control software resides in the DCM

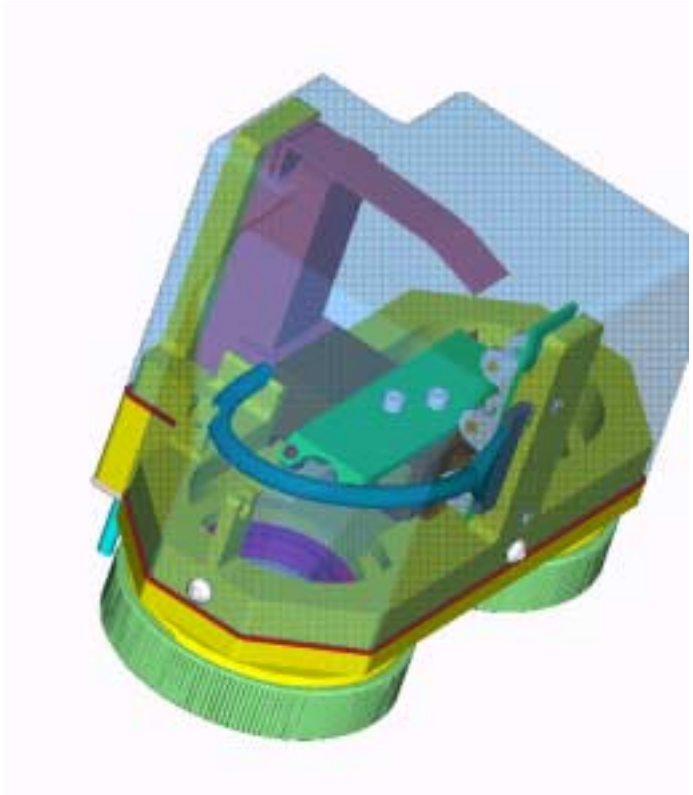
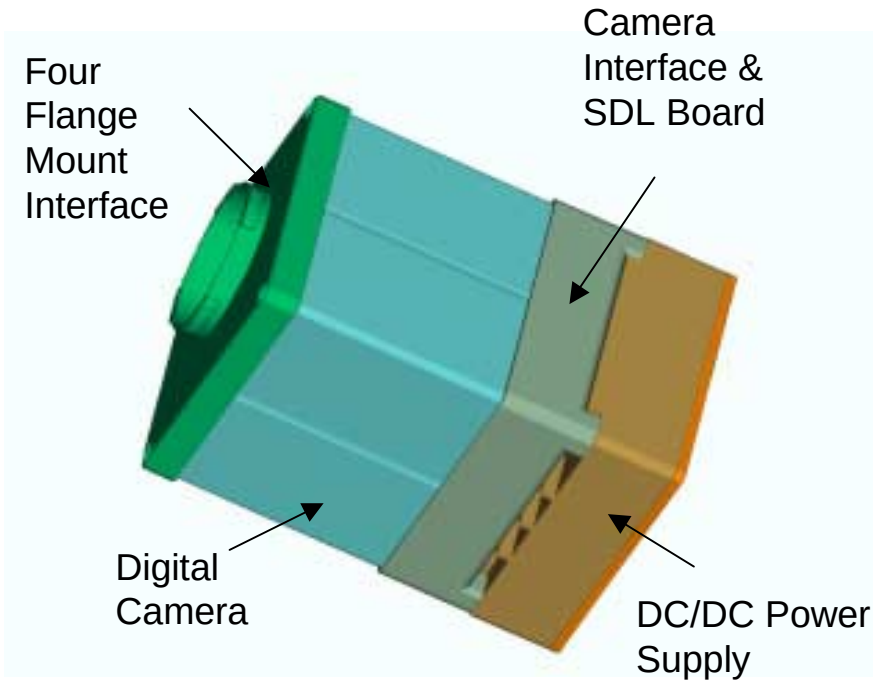


Image Acquisition Modules (IAM)

Features

- Digital Camera collects the image provided to it by the optical system, and converts the incoming photons to digital bit-stream.
- Utilizes Custom DC/DC power converter
- Digital data converted to optical serial data stream via custom SDL board
- Six distinct IAM modules are required for CIR:
  1. HFR/HR Baseline SMD 1M60-20 *
  2. HIBMs Baseline SMD 1M60-10
  3. LLL-IR Baseline SMD 1M30 **
  4. LLL-UV Baseline SMD 1M30 ***
  5. Color Under Evaluation
  6. Mid-IR Under Evaluation



Typical IAM Configuration

* Common Systems Development

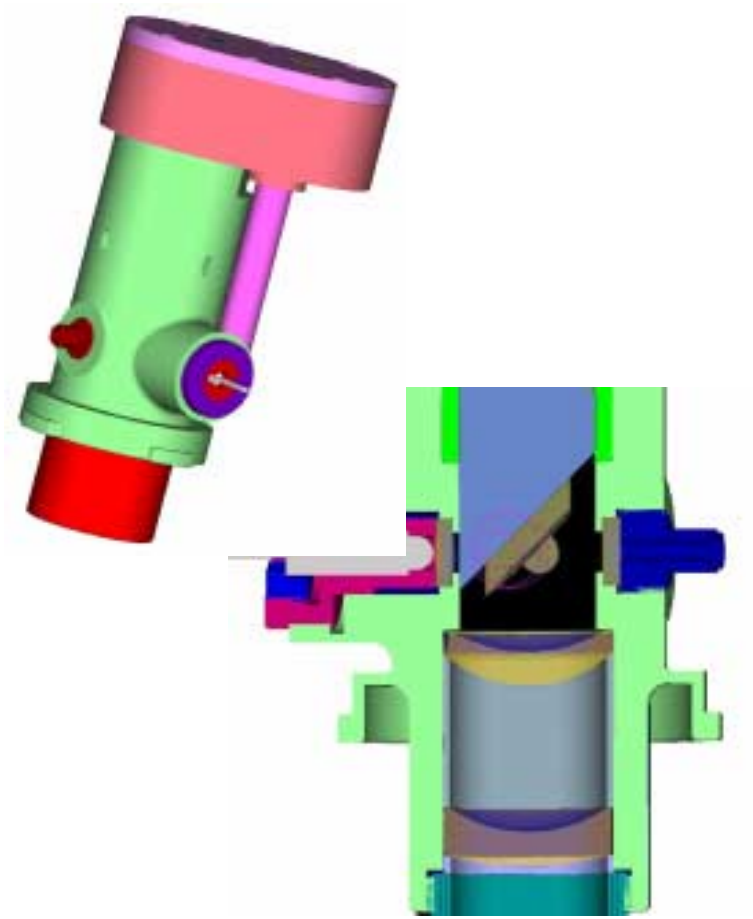
** Modified with Gen III Intensifier

*** Modified with Gen II Intensifier

Illumination Source Module Assembly

Features

- Provides four input locations for light into the Illumination Package
- One port dedicated to the calibration lamp
- Other three ports have a common interface and accept an adapter which is used for connecting light sources or fiber optics
  - One port is the primary illumination fiber coupled laser diode array interface through an SMA 905 connector
  - Two ports are available to accept PI provided illumination through an FC connector
- Ports are selected using a remotely controlled mechanized mirror
  - Position of the selector mirror is be detected by a sensor system



Module Utilization and Status

Module Basic Type	Variations	Where Used	Status
DCM	DCM	All imaging packages	EM detail design
	ICM	Illumination	EM Modeling
IAM	SMD1M60-20	HFR/HR	EM detail design
	12 bit	HiBMs	EM detail design
	Color	Color	Prototype development
	LLL-IR	LLL-IR	Prototype modeling
	LLL-UV	LLL-UV	Prototype modeling
	Mid-IR	Mid-IR	Conceptual
Illumination Source	CIR standard	Illumination	Prototype modeling
Optics Housing	CIR standard	All packages	EM detail design
Objective Optics	HFR/HR	HFR/HR	EM detail design
	HiBMs	HiBMs, Illumination	EM Modeling
	Color (3)	Color (2), LLL-IR (2)	Optical design
	LLL-UV	LLL-UV	Concept development
	Mid-IR	Mid-IR	Concept development
Mirror	Fixed	All packages except HFR/HR	EM detail design
	Pointing	HFR/HR	EM detail design
Filter	LCTF	HiBMs	EM Modeling
	Compensator	HFR/HR	EM detail design
Relay Optics	HFR/HR	HFR/HR	EM detail design
	HiBMs (2)	HiBMs	EM Modeling
	Color	Color, LLL-IR	Optical design
	LLL-UV	LLL-UV	Concept development
	Mid-IR	Mid-IR	Concept development
Focus Prism	HFR/HR	HFR/HR	EM detail design
IPSU	Common IPSU	Color, LLL-IR, LLL-UV, Mid-IR	EM detail design
	IPP	HFR/HR, HiBMs	EM detail design

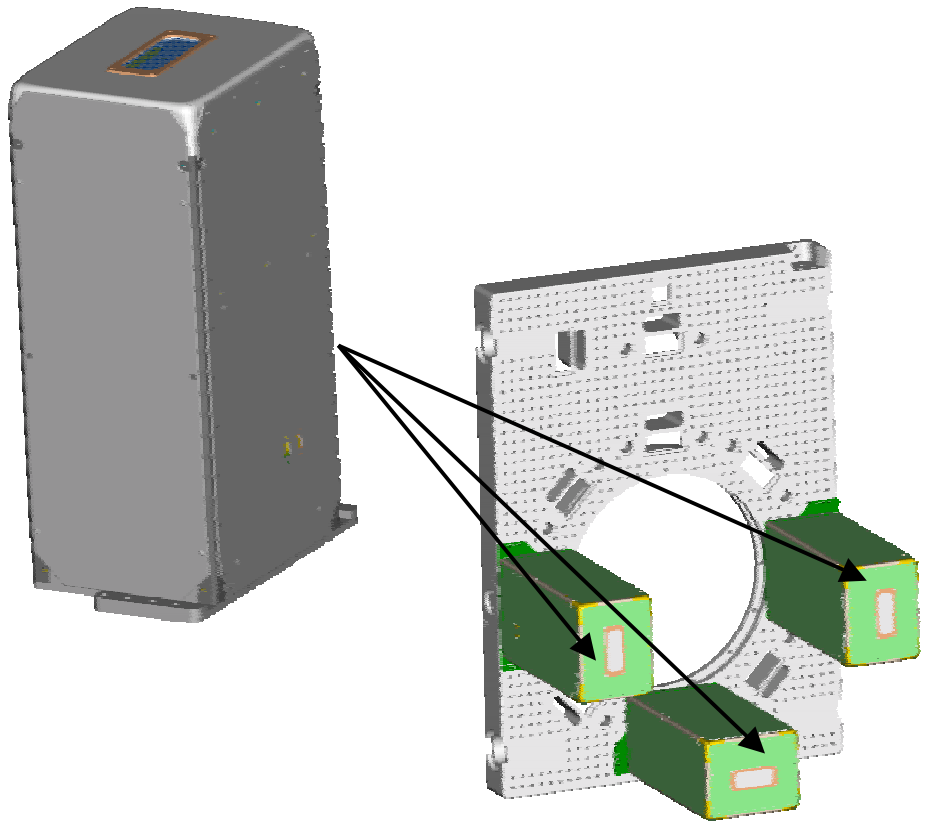
Image Processing Package – Overview

- The IPP is an ORU that contains two independent Image Processing and Storage Units (IPSU's).
- An IPP IPSU acquires images from an FCF high resolution IAM or an imaging diagnostic package that has an equivalent data interface.
- The IPP can be relocated to accommodate different experiments

Image Processing Package

Each IPSU performs the following functions:

- Configure and control one imaging diagnostic package and one illumination package
- Acquire and store digital images from an imaging diagnostic package
- Perform real time image processing for open or closed-loop control of an imaging diagnostic package
- Capture and record ancillary data such as date & time
- Perform near-real time and post-test data reduction and compression
- Transfer images data and ancillary data to the IOP for downlinking
- Provide real-time analog video output
- Support SMD 1M60-10 and 1M60-20 IAM modules
- Provides hardware implemented processing routines to support CIR tracking requirements



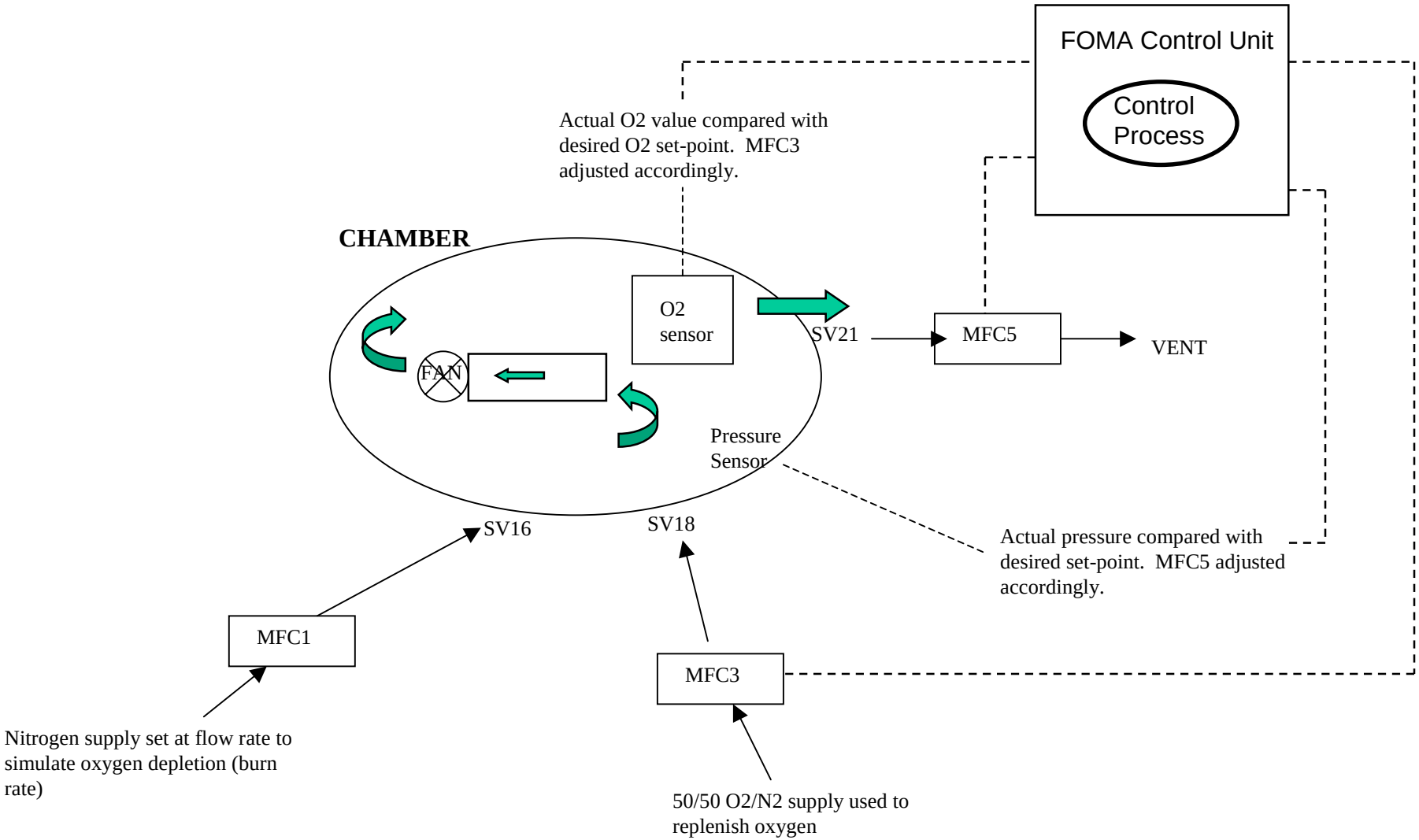
The IPP mounts on the CIR optics bench at UML ports 3, 5, & 7.

System Level Design Changes from PDR

FOMA Oxidizer Bleed-In Capability

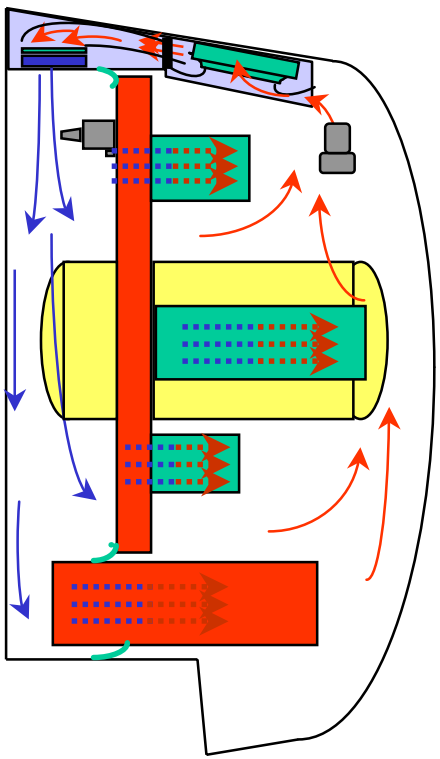
- **Background**
  - Method developed to address experiment oxidizer velocities greater than direct delivery from the FOMA (> 1,500 scc/sec)
  - FOMA would maintain oxidizer concentration levels and chamber pressure while experiment fans develop required velocities
- **Methodology**
  - Oxygen replenishment matches experiment consumption rate
  - Chamber is vented to ISS VES at specified rate to keep pressure constant
  - Venting route can be direct to ISS VES or single pass through the Adsorber Cartridge to ISS VES
  - Oxygen sensor inside chamber detects and adjusts oxidizer input
- **Performance Testing**
  - Oxygen levels have been maintained within +0% to –0.5% of desired concentration
  - Pressure levels have been maintained within 0.01 atm of desired pressure
  - Oxygen consumption rates up to 0.06 g/s have been tested
  - Higher O2 consumption rates are being evaluated based on Basis Experiment descriptions

FOMA Oxidizer Bleed-In Control Process

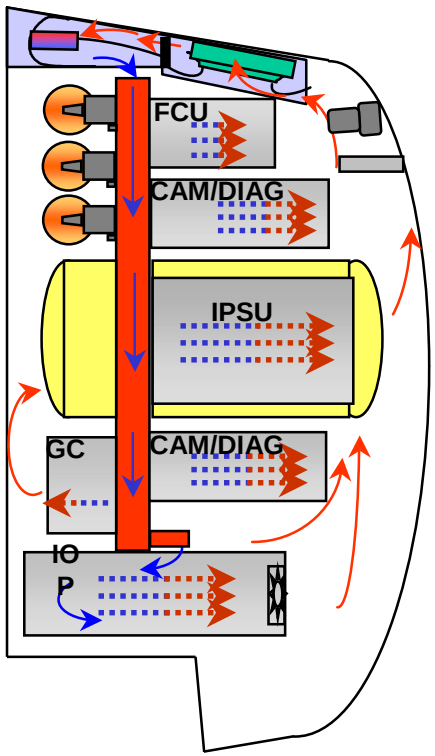


Air Thermal Control Design

CIR PDR Design



CIR Delta-PDR Design



- Maximum ATCU Subsystem commonality was preserved by modifying flow design. Design uses the Optics Bench as a flow duct.
  - CIR – Pressurize Duct
- Elimination of Optics Bench Seal
  - Eliminate design challenge of sealing around irregular structural shapes

CIR Grounds Systems, Integration, Operations and Utilization

CIR to ISS Integration

PIA Status

- FCF PIA baselined June 2000
- DCN-01 incorporated October 2000
  - ARIS Roles and Responsibilities added
- Update planned late 2001 to update for blank book changes

Payload Integration Schedule Status

- Current schedule has buy-in by rack and subrack payload teams
- Schedule frozen until completion of PDR
- Updates will be necessary in keeping with CDR replanning
- Reconciliation with Rev. F assembly sequence is pending

ICD Status

- Current draft contains only 25 TBDs remaining to be detailed
- Update planned for late 2001

CIR Exceptions

Exceptions Approved

- 57217-NA-001A - CIR Optics Bench Protrusion Exception
  - PCB approval for full requested envelope on 4/29/99
- 57217-NA-0002 – CIR Mass Exception
  - PCB approval for 1100kg on 1/10/01
- 57217-NA-0003A – CIR Door Protrusion Exception
  - PCB approval for full requested envelope on 9/27/00

Exceptions In-Process at ISS

- None

Exceptions to be Submitted to ISS

- Ground mass exception
- Diagnostics Package Pin ID, Connector Arrangement, and Ease of Disconnect
- IPP Accessibility
- Rack to Rack Cabling

MDCA to CIR Integration Status

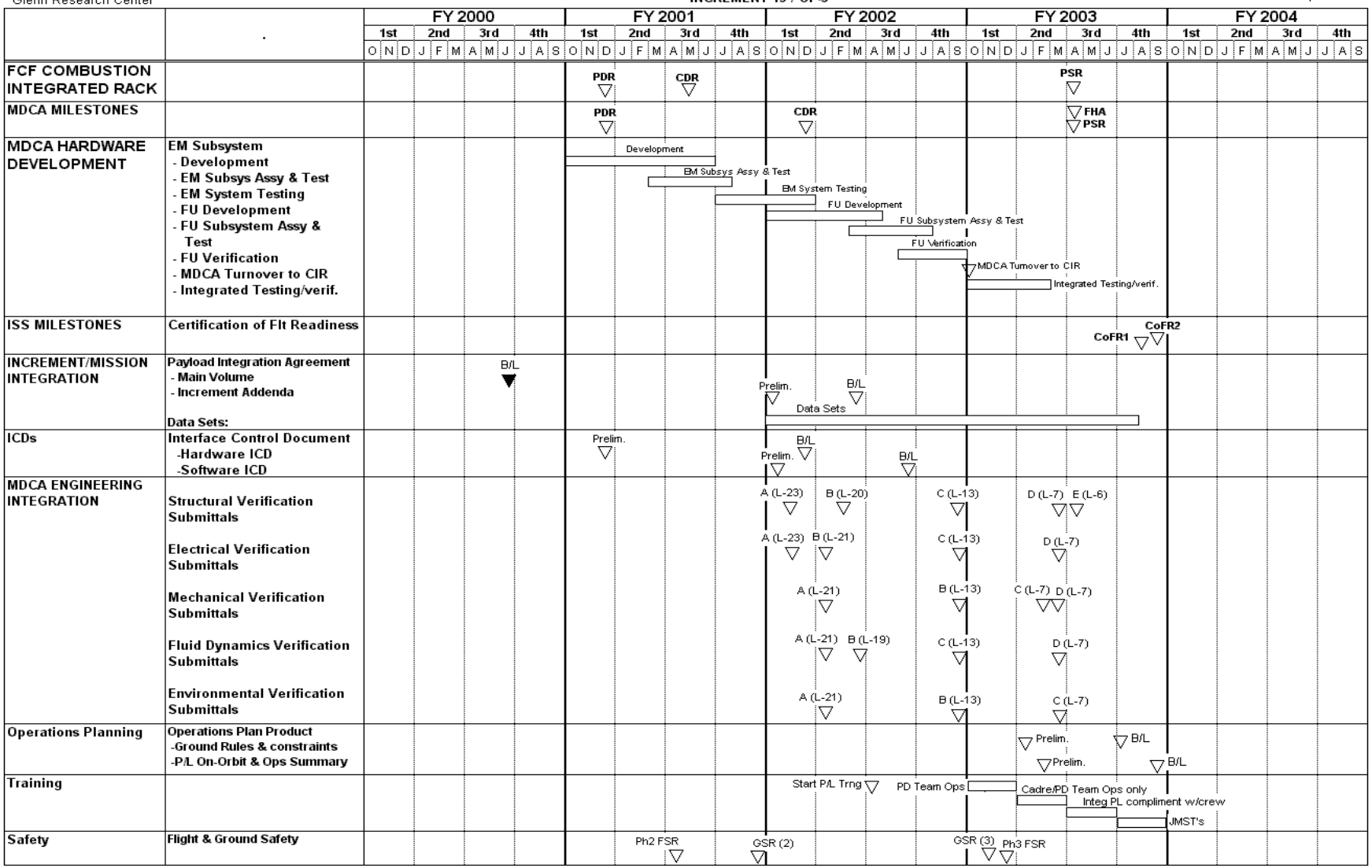
- MDCA integration agreement main volume developed
- MDCA draft ICD developed
- Integration schedule developed
- Regular meetings being held between the engineering teams to clarify interface requirements

Glenn Research Center

CIR - MDCA INTEGRATION SCHEDULE

INCREMENT 13 / UF-5

Jan 31, 2001



CIR System Topics

CIR Mass Summary

	Assembly	Base Estimate (Kg)	Control Mass (Kg)	Margin (Kg)	Percent Margin	Installed During Launch ?	Installed During Operation?
CIR Unique Hardware	Chamber - Chamber Assembly	139.2	140.1	0.9	0.63%	Y	Y
	Diagnostics - Color Camera	9.4	10.4	1.0	11.06%	**N**	Y
	Diagnostics - UV Camera	11.4	12.8	1.4	11.84%	**N**	Y
	Diagnostics - HiBMS Camera	9.1	9.8	0.6	7.11%	**N**	Y
	Diagnostics - Mid-IR Camera	9.8	11.0	1.2	12.28%	**N**	Y
	Diagnostics - HFR/HR Camera	8.8	9.3	0.5	5.66%	**N**	Y
	Diagnostics - Illumination	8.6	9.6	0.9	11.02%	**N**	Y
	Diagnostics - IPP	18.2	19.2	1.1	5.96%	**N**	Y
	FOMA	78.3	79.7	1.4	1.78%	Y	Y
	FOMA - FCU	14.4	15.0	0.6	4.32%	**N**	Y
	FOMA - Gas Chromatograph Launch Mass	9.4	9.7	0.4	3.78%	Y	Y
	FOMA - Gas Chromatograph Additional On-Orbit Mass	11.5	13.1	1.6	13.91%	**N**	Y
	FOMA - Bottle (3.8L)	10.1	10.5	0.4	4.37%	**N**	Y
	FOMA - Bottle (3.8L)	10.1	10.5	0.4	4.37%	**N**	Y
	FOMA - Bottle (3.8L)	10.1	10.5	0.4	4.37%	**N**	Y
	FOMA - Absorptive Filter (Large)	4.7	4.9	0.2	4.47%	**N**	Y
	Optics Bench - Optics Bench Assembly	109.6	110.0	0.4	0.36%	Y	Y
Common Systems	Diagnostics - IPSU's (2)	15.6	16.0	0.4	2.52%	Y	Y
	Diagnostics - DCMs (6)	13.0	13.4	0.3	2.53%	**N**	Y
	Rack -Doors Assembly	20.1	25.6	5.5	27.51%	Y	Y
	Rack - Rack Attachment Hardware	65.8	67.4	1.6	2.50%	Y	Y
	IOP - I/O Processor	24.7	25.3	0.6	2.51%	Y	Y
	IOP - I/O Processor Harddrives	4.4	4.6	0.1	2.48%	**N**	Y
	Diagnostics - Removable Latch	2.6	2.6	0.1	2.33%	**N**	Y
	ECS - Water Distribution & Control Assy	32.5	33.4	0.8	2.51%	Y	Y
	ECS - Accumulator Assembly (removed on orbit)	1.8	1.9	0.0	2.72%	Y	**N**
	ECS - Air Thermal Control Assembly	39.5	40.4	1.0	2.50%	Y	Y
	ECS - Gas Interface Assy	16.2	16.6	0.4	2.50%	Y	Y
	ECS - Fire Detection & Supression Assy	2.2	2.3	0.1	2.61%	Y	Y
	EA - Service Umbilical Set & ESSA Switch	6.5	6.6	0.2	2.52%	Y	Y
PI	Chamber - Chamber Insert Assembly	40.0	40.0	0.0	0.00%	**N**	Y
	Diagnostics - PI-Specific Electronics	14.4	14.4	0.0	0.00%	**N**	Y
GFE	ARIS - Launch Condition*	61.1	61.1	0.0	0.00%	Y	Y
	ARIS - Additional On-Orbit Mass*	14.5	14.5	0.0	0.00%	**N**	Y
	EPS - Electrical Power Control Unit	48.5	48.5	0.0	0.00%	Y	Y
	EPS - EPCU Umbilicals	2.8	2.8	0.0	0.00%	Y	Y
	EPS - RMSA Switch	0.6	0.6	0.0	0.00%	Y	Y
	SAMS - SAMS Subsystem	1.2	1.2	0.0	0.00%	Y	Y
	Rack - Rack Assembly	111.9	111.9	0.0	0.00%	Y	Y
	Rack - Rack-to-Station I/F Umbilical Set	10.7	10.7	0.0	0.00%	**N**	Y
	Management Reserve		52.0	52.0			

CIR Core Systems On-Orbit Mass

		Assembly	Base Estimate (Kg)	Control Mass (Kg)
CIR CORE SYSTEMS	[redacted]	Optics Bench - Optics Bench Assembly	109.6	110.0
		Chamber - Chamber Assembly	139.2	140.1
		FOMA, FCU and GC	113.6	117.5
	Common	Rack -Doors Assembly	20.1	25.6
		Rack - Rack Attachment Hardware	65.8	67.4
		IOP - I/O Processor	29.1	29.9
		Environmental Control System	90.4	92.7
		EA - Service Umbilical Set & ESSA Switch	6.5	6.6
	GFE	ARIS - Launch Condition*	75.6	75.6
		EPS - Electrical Power Control Unit	48.5	48.5
		EPS - EPCU Umbilicals	2.8	2.8
		EPS - RMSA Switch	0.6	0.6
		SAMS - SAMS Subsystem	1.2	1.2
		Rack - Rack Assembly	111.9	111.9
		Rack - Rack-to-Station I/F Umbilical Set	10.7	10.7
Core Operating Configuration Totals			**825.7**	**841.2**

CIR Configurable On-Orbit Components

Assembly	Base Estimate (Kg)	Control Mass (Kg)
Chamber - Chamber Insert Assembly	40.0	40.0
Diagnostics - PI-Specific Electronics	14.4	14.4
Diagnostics - PI-Provided Illumination	10.8	10.8
Diagnostics - Color Camera	9.4	10.4
Diagnostics - UV Camera	11.4	12.8
Diagnostics - HiBMS Camera	9.1	9.8
Diagnostics - Mid-IR Camera	9.8	11.0
Diagnostics - HFR/HR Camera	8.8	9.3
Diagnostics - Illumination	8.6	9.6
Diagnostics -Intensified Near IR Imaging Package	11.9	12.2
Diagnostics - IPP	18.2	19.2
Diagnostics - IPSU	7.8	14.5
Diagnostics - DCM	2.2	12.0
FOMA - Bottle (3.8L)	10.1	10.5
FOMA - Bottle (2.25L)	6.7	7.4
FOMA - Bottle (1.0L)	4.0	4.4
FOMA - Absorptive Filter (Large)	4.7	4.9
FOMA - Absorptive Filter (Medium)	3.0	3.3
FOMA - Absorptive Filter (small)	2.5	2.8

CIR Mass Summary

Hardware Configuration	Base Mass (Kg)	Margin	Requirement
Launch	787.6	2.03%	804.0
Operating	1021.5	7.13%	1100.0
CIR (without PI Hardware)	825.7		
PI Fully Populated Configuration	195.9		

Mass Exception	1100.0
Core Systems Mass	(841.2)
Management Reserve	(52.0)
Configurable Mass	206.8

Thermal Heat Rejection Allocations

CIR Hardware Assembly			Power Estimates				
			Typical @ 28 VDC (Watts)	Maximum @ 28 VDC (Watts)	Typical @ 120 VDC (Watts)	Maximum @ 120 VDC (Watts)	Heat Rejection Mode
		Diagnostic Control Module	48.0	48.0	0.0	0.0	air
		Common IPSU	150.0	150.0	0.0	0.0	air
		ITI IPSU	136.0	136.0	0.0	0.0	air
	Science Diagnostics	Image Acquisition Module 1 (LLL-UV)	50.0	50.0	0.0	0.0	air
		Image Acquisition Module 2 (LLL-IR)	50.0	50.0	0.0	0.0	air
		Image Acquisition Module 3 (Near-IR)	50.0	50.0	0.0	0.0	air
		Image Acquisition Module 4 (Color)	50.0	50.0	0.0	0.0	air
	Specific Science Packages	SCIENCE (PI BOX)	450.0	450.0	0.0	0.0	air
		SCIENCE (CHAMBER)	500.0	500.0	0.0	0.0	water
Core Elements		IOP	155.0	155.0	0.0	0.0	air
		FCU/FOMA	137.0	137.0	0.0	0.0	air
		ARIS (electronics)	39.0	87.0	0.0	0.0	air
		ARIS	2.4	8.0	0.0	0.0	cabin air
		ARIS (rack)	0.0	0.0	72.7	190.0	water
		WTCS WFCA #1	6.0	18.0	0.0	0.0	water
		WTCS WFCA #2	6.0	18.0	0.0	0.0	water
		ATCS (Fans)	100.0	100.0	0.0	0.0	air
		EEU	51.0	51.0	0.0	0.0	air
		SSC	39.2	39.2	0.0	0.0	cabin air
		SAMS	2.0	2.0	0.0	0.0	air
		FDSS	0.0	0.0	3.0	3.0	air
		Cable Losses (vary as function of total rack power)	41.3	42.8	1.5	3.9	air
		EPCU LOSSES (vary as function of total rack power)	265.8	276.2	61.0	62.5	water

Hardware Non-Compliances

Non-Captive Fasteners on Several Components

- Components include:
  - Optics Bench Attachment Hardware
  - Door Launch Restraints
  - Rack Attachment Hardware for ATCU, EPCU, and IOP
- Mitigation strategy includes:
  - Plan to identify captive alternatives for each assembly
  - Resolution should occur by April 2001

IPP Accessibility

- Installation and removal of the IPP involves mating and de-mating an electrical connector – the UML ARINC connector
- When installed in the CIR, the IPP will be bolted to the optics bench
- Because of their close proximity, it may not be possible to install or remove the IPP without removing adjacent diagnostic packages
- Will seek a waiver to this requirements pending crew consensus.

Hardware Non-Compliances – Continued

Diagnostics Package Connector Requirements

- Pin ID
- Connector Arrangement
- Ease of Disconnect
  - All affected by use of Airborn Connectors
  - Connector reviewed with Crew Office in November 2000. Consensus report is pending.

Diagnostics Kick Loads

- Mitigation strategy includes:
  - Assessing applicability of kickoff loads to our bench components
  - Performing analysis and design enhancement activity to beef up components where necessary
  - Resolution should occur by June 2001

Issues and Risks

CIR RISK Statements

Risk Name: CIR Mass

Priority: 1 **Risk Level:** Medium

Condition: CIR launch mass has than 2% margin to requirement

Status/Mitigation:

- On-Orbit Mass Exception for 100 kg approved on 1/10/01
- CIR Optics Bench, Bench Launch Brackets and Chamber designs will be optimized for additional launch mass margins
- FCF-PLN-0034 Mass Control Plan has been instituted
- Goal is to achieve 3% margin for launch and on-orbit configuration by CDR

CIR RISK Statements – Continued

Risk Name: HRDL I/F

Priority: 1 **Risk Level:** Medium

Condition: HRDL I/F design schedule does not support CIR EM testing

Status/Mitigation:

- Boeing/GFE HRDL card design is not documented and FCF has been unable to obtain adequate technical support to implement this design.
- Alternative design approach has been identified. Procurement of candidate I/F board has been authorized.
- Testing and implementation schedule will not support planned qualification of the IOP.

CIR RISK Statements – Continued

Risk Name: Oxidizer Flow Rate

Priority: 2 **Risk Level:** Medium

Condition: CIR Oxidizer flow-through capability is limited to 1500 scc/sec

Status/Mitigation:

- Capability to maintain constant O2 percentage can be substituted for flow-through flow rate
- FOMA O2 Bleed-in process has been developed
- Additional testing is required to establish CIR Oxygen bleed-in capabilities used to maintain the specified environment for experiment burn rates
- Requirements for oxygen bleed-in need to be established with the project

CIR RISK Statements – Continued

Risk Name: ARIS Performance

Priority: 2 **Risk Level:** Medium

Condition: ARIS Performance with 1100 Kg Rack and CIR RUP panel interfaces has not been assessed.

Status/Mitigation:

- CR 3272 is being developed perform analysis of ARIS performance for CIR. Approval is still pending.
- FCF has submitted a CIR integrated FEM dynamic model to support this analysis.

CIR RISK Statements – Continued

Risk Name: ATCU Heat Exchanger Design

Priority: 3 **Risk Level:** Medium

Condition: EM heat exchanger delivery is after CIR CDR

Status/Mitigation:

- Heat Exchanger RFP and specification has been issued, evaluating responses
- Delivery of prototype h/w is 7-12 months away
- RFP requires submittal of analysis and test data
- All package level analysis performed to date are based on performance of the Hx
- CIR air heat loads near the limit of the Hx performance curve

CIR RISK Statements – Continued

Risk Name: Integrated Rack Primary Mode

Priority: 3 **Risk Level**: Low

Condition: CIR Launch Configuration Primary Mode is Less than 25 hz.

Status/Mitigation:

- Design assessment indicates that rack stiffness to achieve 25 hz can not be achieved with-in current design concept.
- Require a coupled loads analysis to be preformed by Boeing prior to CDR to assure load factors used for design are conservative

CIR Issues – ARIS

CR 3272

- Pending approval will affect timeliness of data to support CIR development schedule

ARIS Simulator

- FCF has identified need date of February 2001 to support IOP software development
- ARIS has proposed sending flight unit controller to support FCF simulator needs and backfilling FEU for flight
  - Functional equivalent controller being backfilled needs to be upgraded to flight quality requirements
  - Requires approval of CR 3272 and completion of flight hardware fabrication
  - Delivery date commitment is required

ARIS Standard Documentation

- ICD
  - ARIS plan to initiate CR by February 2001 to baseline ICD revision
  - Draft document indicates new RS-232 interface for FCF
- User's Guide
  - Complete rewrite of document is planned
  - Missing information impacting FCF/ARIS software interface development
  - Delivery date and software point of contact are required